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Yamaguchi et al.

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(54) **WIRE SPRING FORMING APPARATUS**

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(73) Assignee: **Orii & Mec Corporation**, Kawanaga (JP)

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B21F 35/02 (2006.01)

(52) **U.S. Cl.** **72/138**; 72/137

(58) **Field of Classification Search** 72/137, 72/138, 130, 131, 428, 449
See application file for complete search history.

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(57) **ABSTRACT**

A high-speed wire spring forming apparatus capable of easily adjusting a coil diameter is provided that includes: a wire feeder having a pair of feeding rollers for feeding a wire to a spring forming stage via a quill serving as a wire guide; a revolving mechanism for revolving the feeding rollers about the axis of the wire to twist the wire fed out of the leading end of the quill to change the circumferential position, or angular position, of the wire; and a multiplicity of spring forming tools arranged radially on a spring forming stage, each of the spring forming tools movable in a direction substantially perpendicular to the axis of the wire.

8 Claims, 15 Drawing Sheets

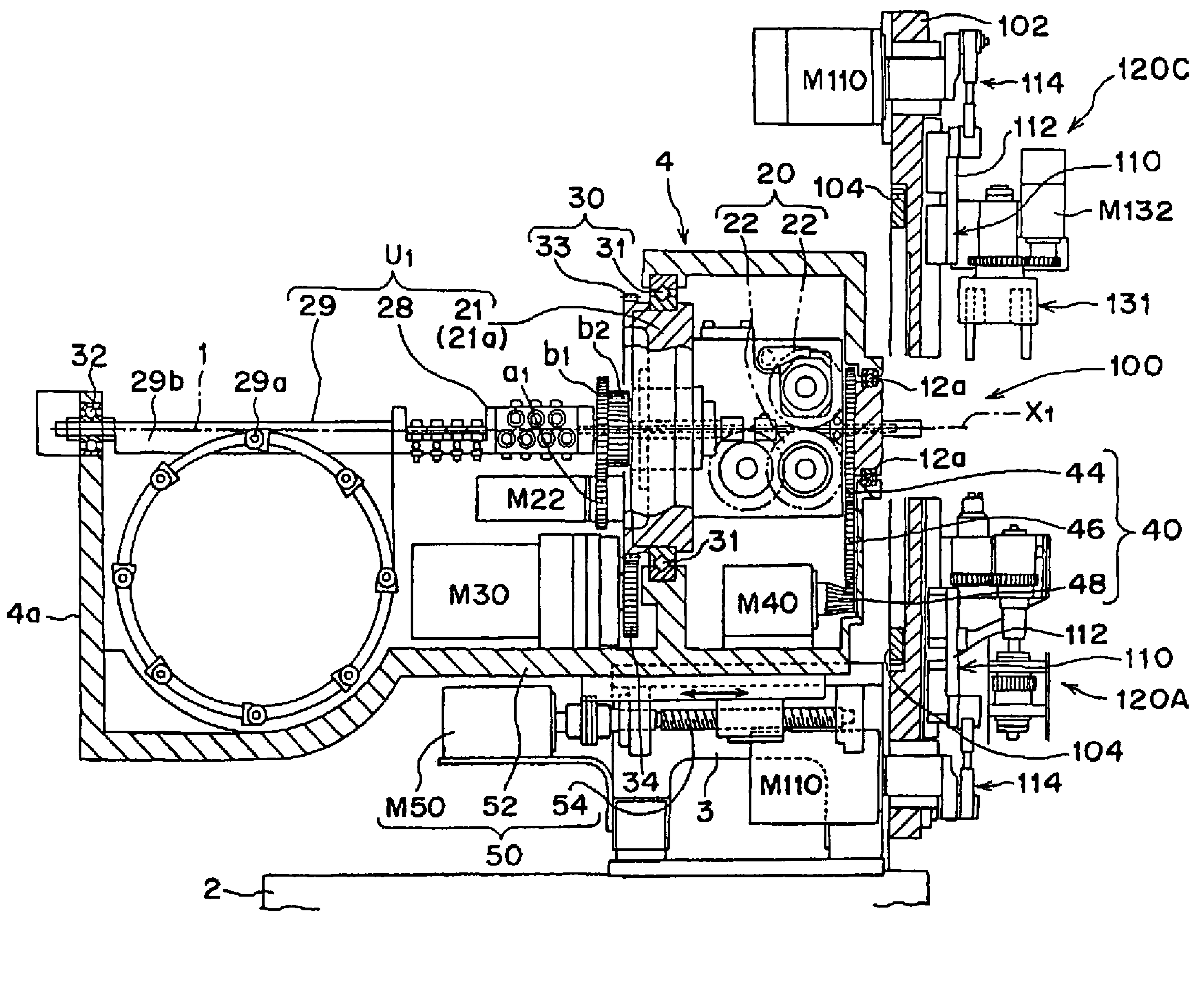
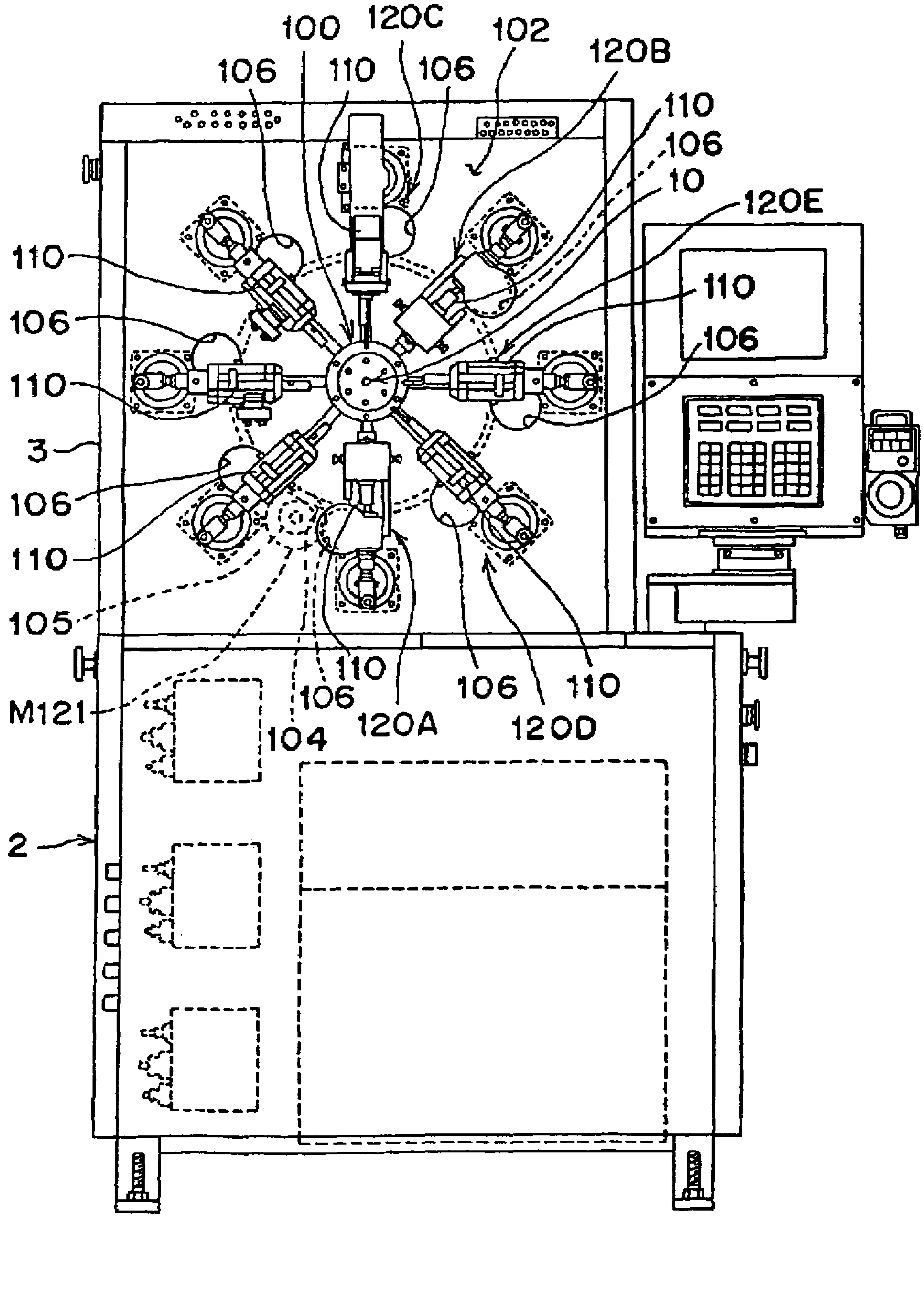


Figure 1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120C
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106
110
106
120B
110
106
10
120E
110
106
110
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110
3
106
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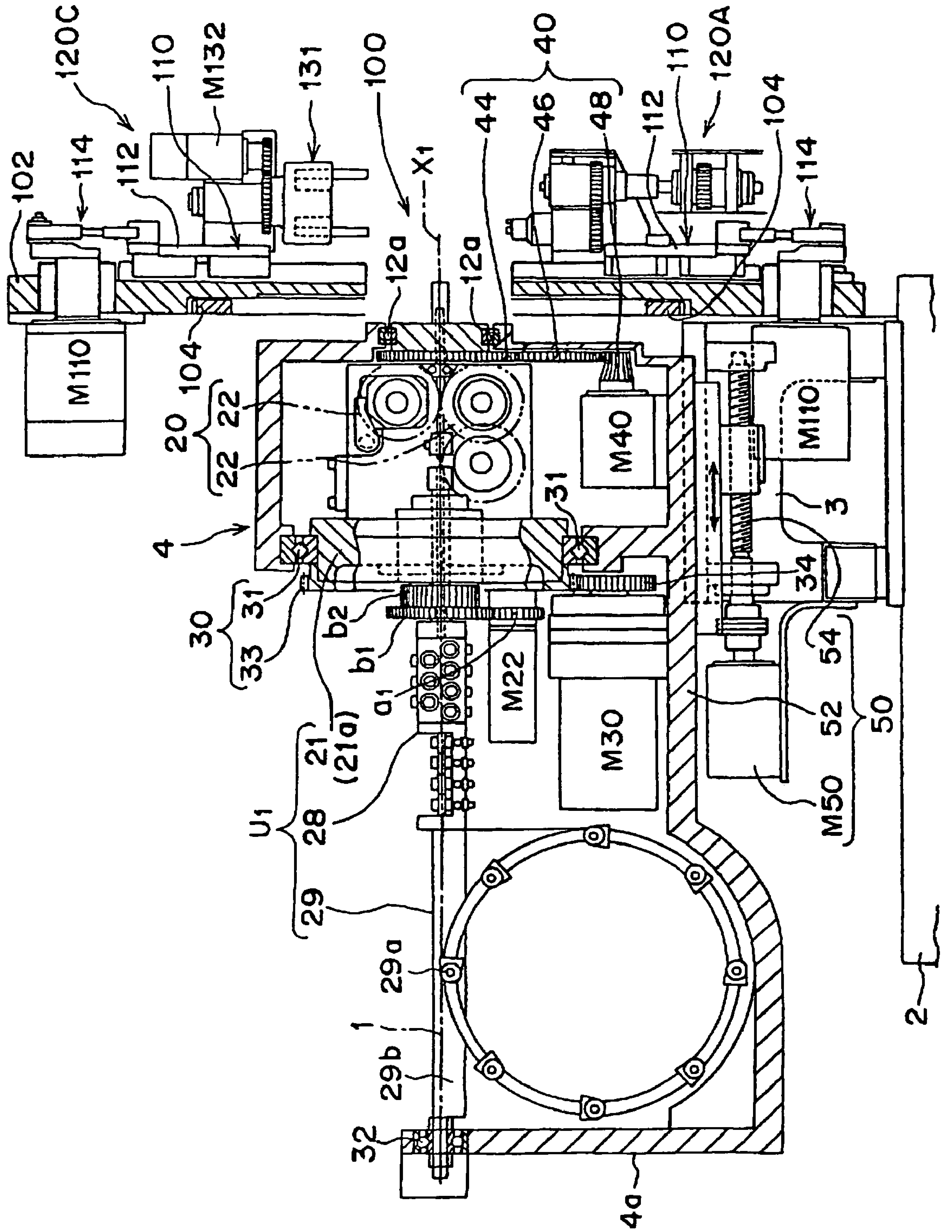
105
M121
110
106
104
120A
106
110
120D
2

Figure 2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M132
110
131
100
X1
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46
48
40
112
110
120A
104
114
102
114
112
12a
12a
104
M110
20
22
22
M40
M110
4
31
3
30
31
33
34
54
b2
b1
a1
M22
M30
52
50
M50
U1
21
(21a)
28
29
29a
29b
1
32
4a
2

Figure 3

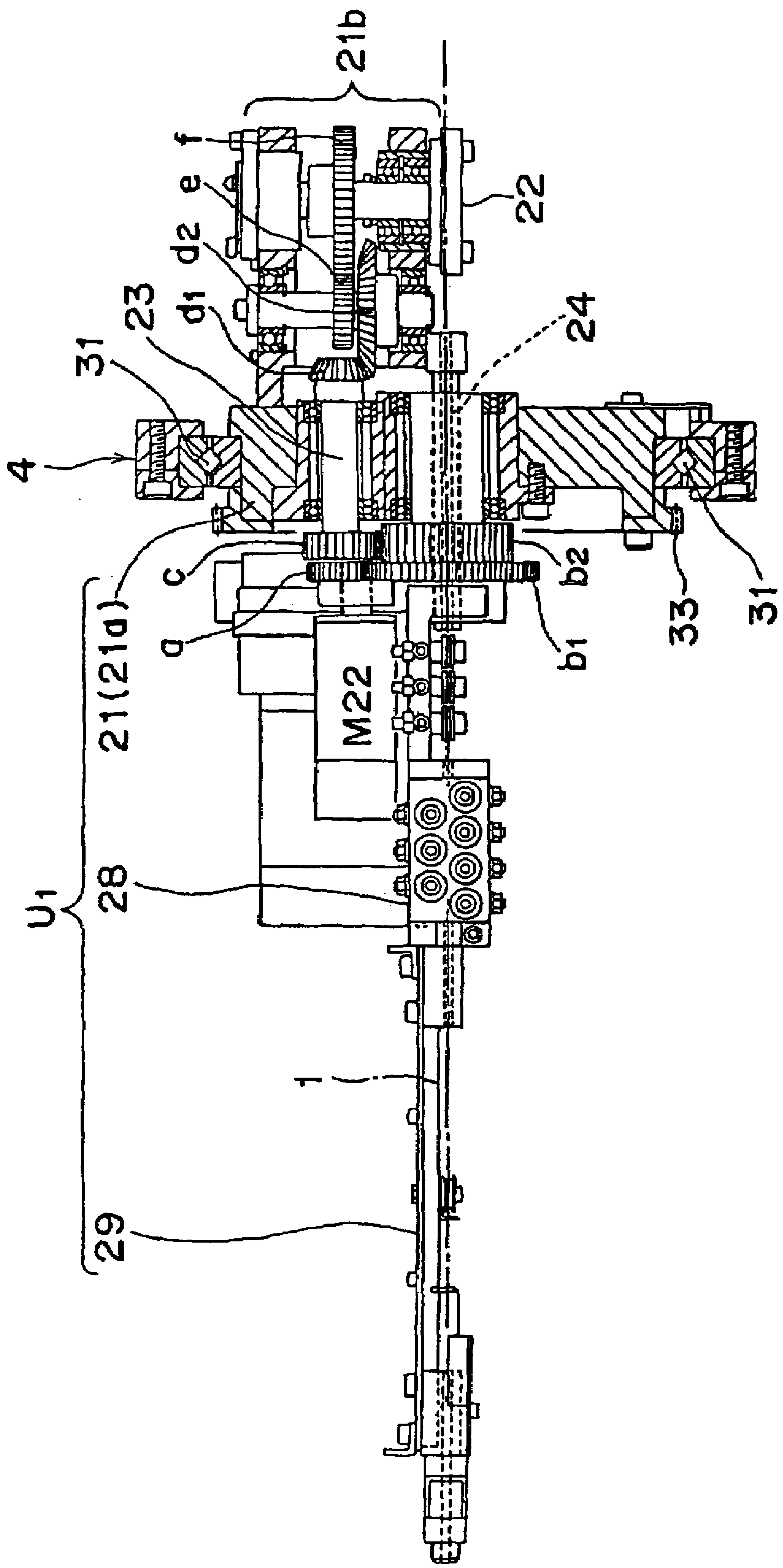


Figure 4

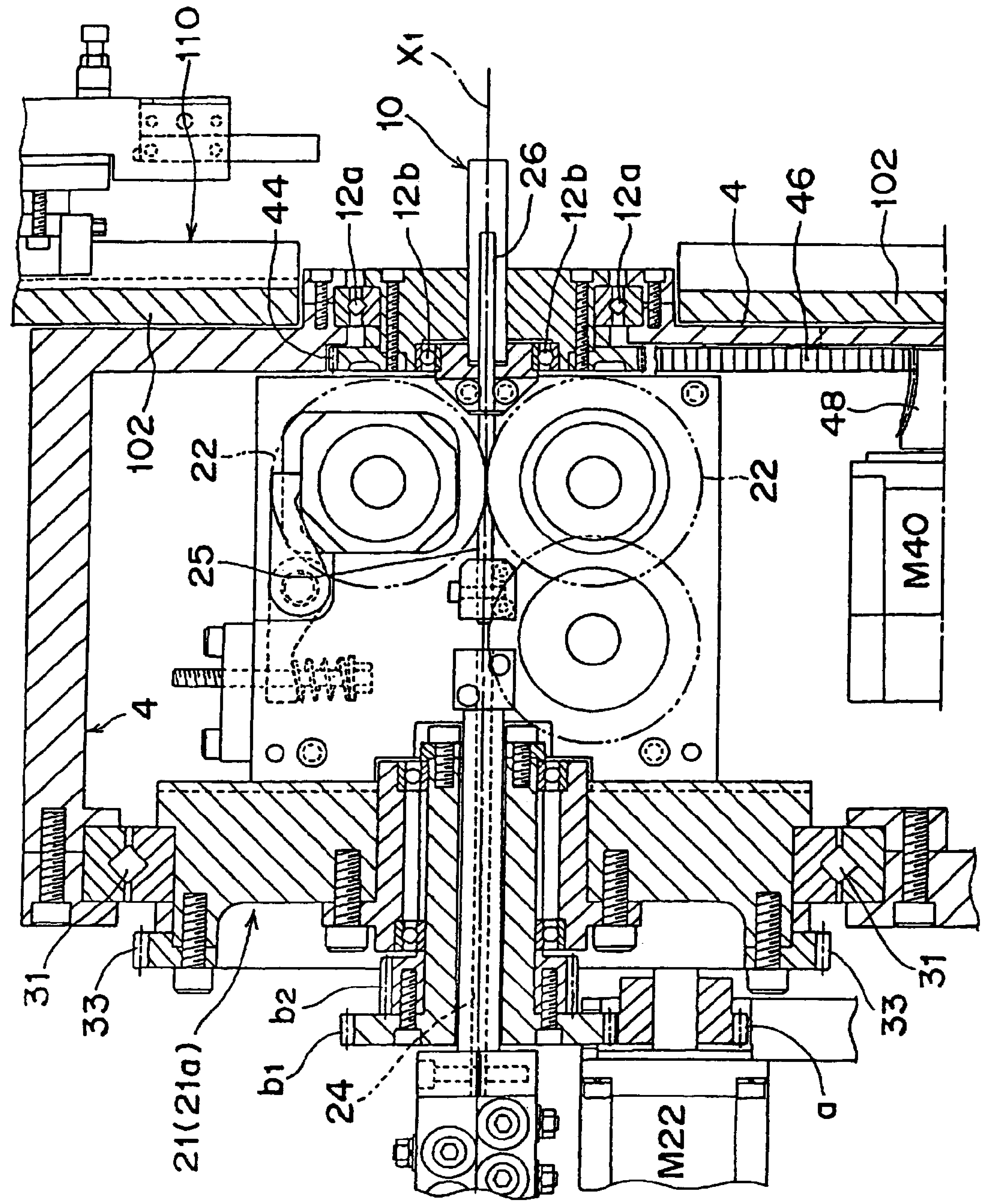

X1
10
26
12b
12a
12b
12a
44
110
4
46
102
102
48
22
22
25
M40
4
31
33
21(21a)
b2
b1
24
M22
a
33
31

Figure 5

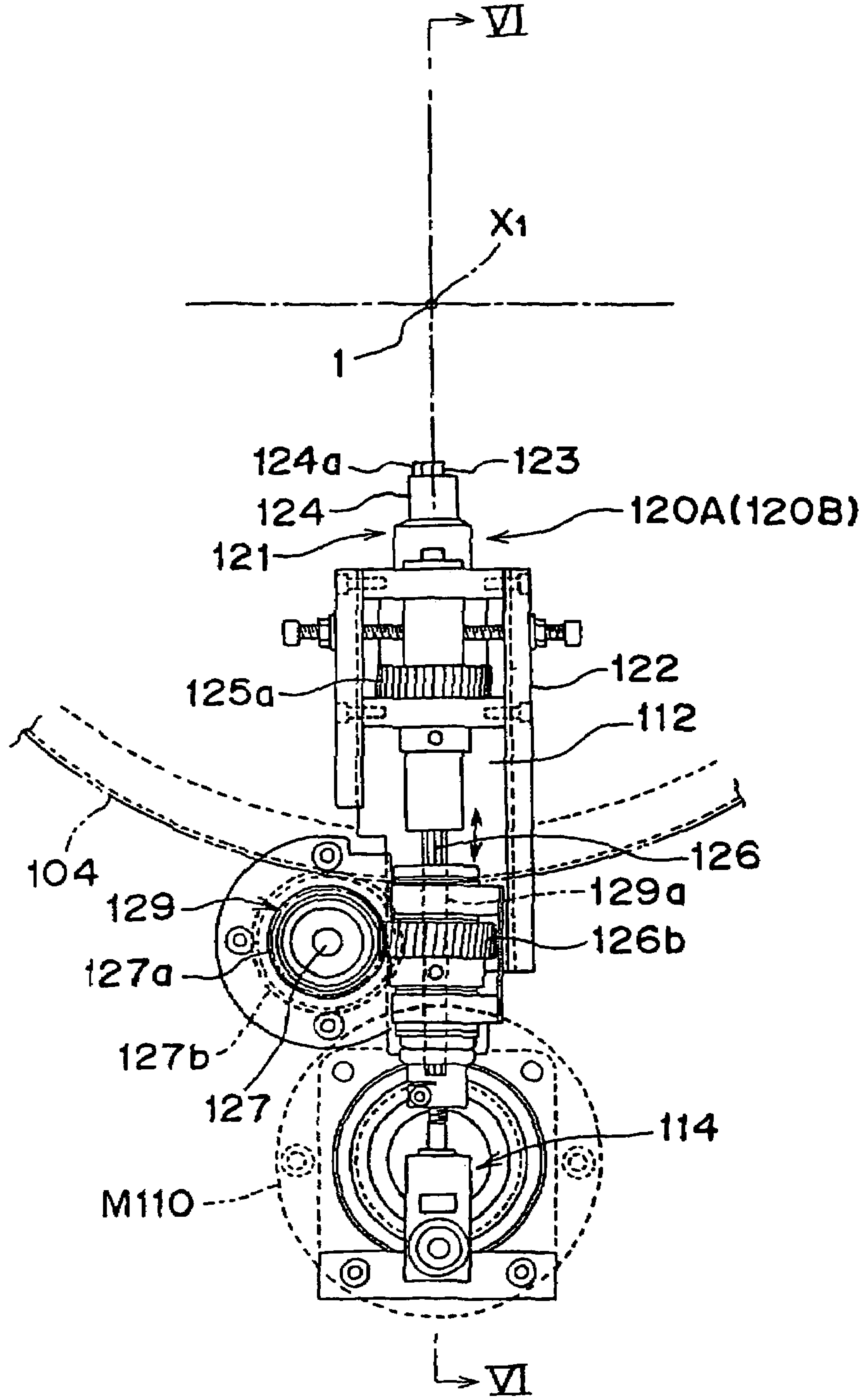
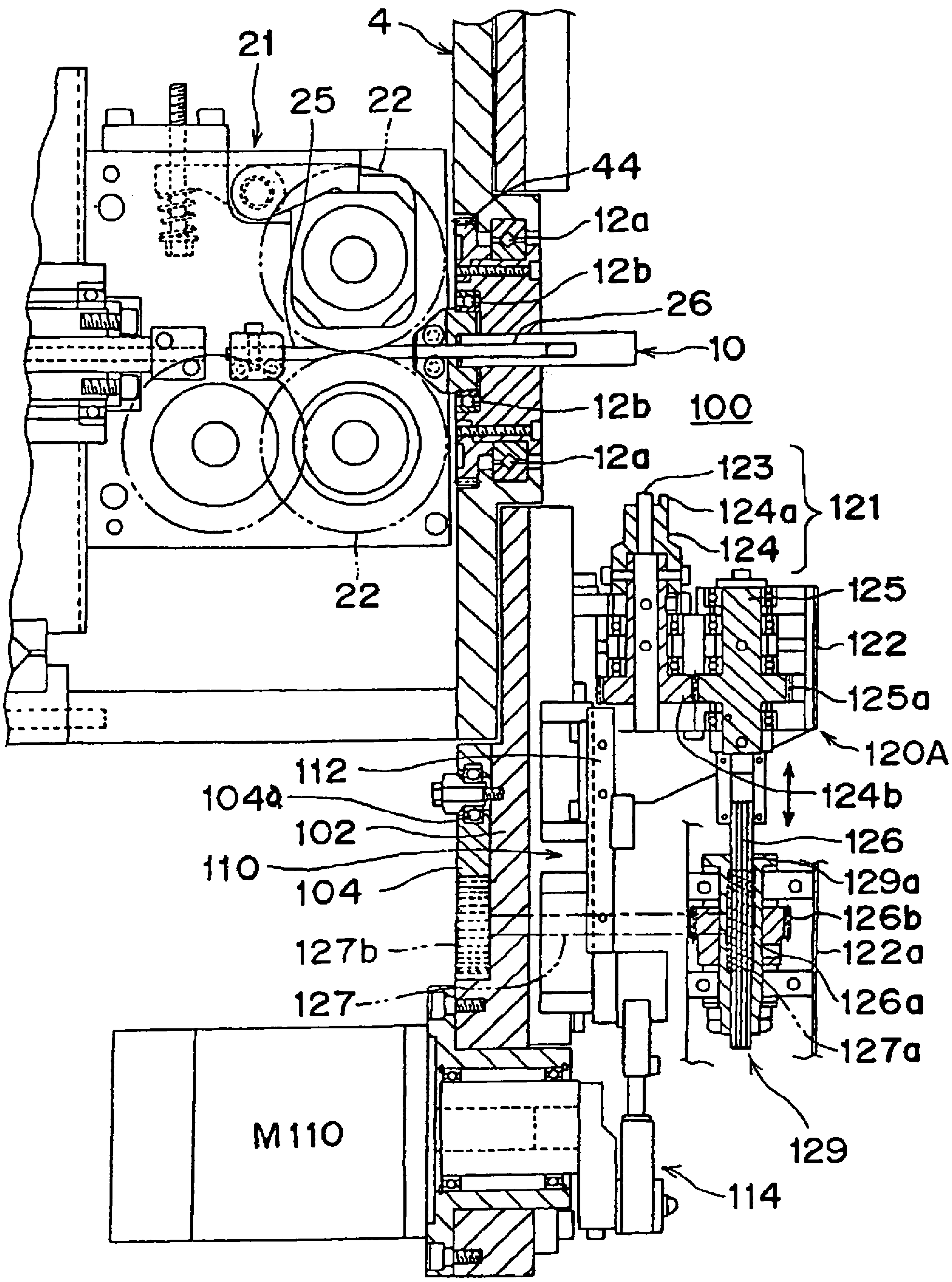

VI
X1
1
124a
123
124
120A(120B)
121
122
125a
112
104
126
129
129a
126b
127a
127b
127
114
M110
VI

Figure 6


4
21
25
22
44
12a
12b
26
10
12b
100
12a
123
124a
121
124
22
125
122
125a
120A
112
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126b
127b
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126a
127
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M110
129
114

Figure 7

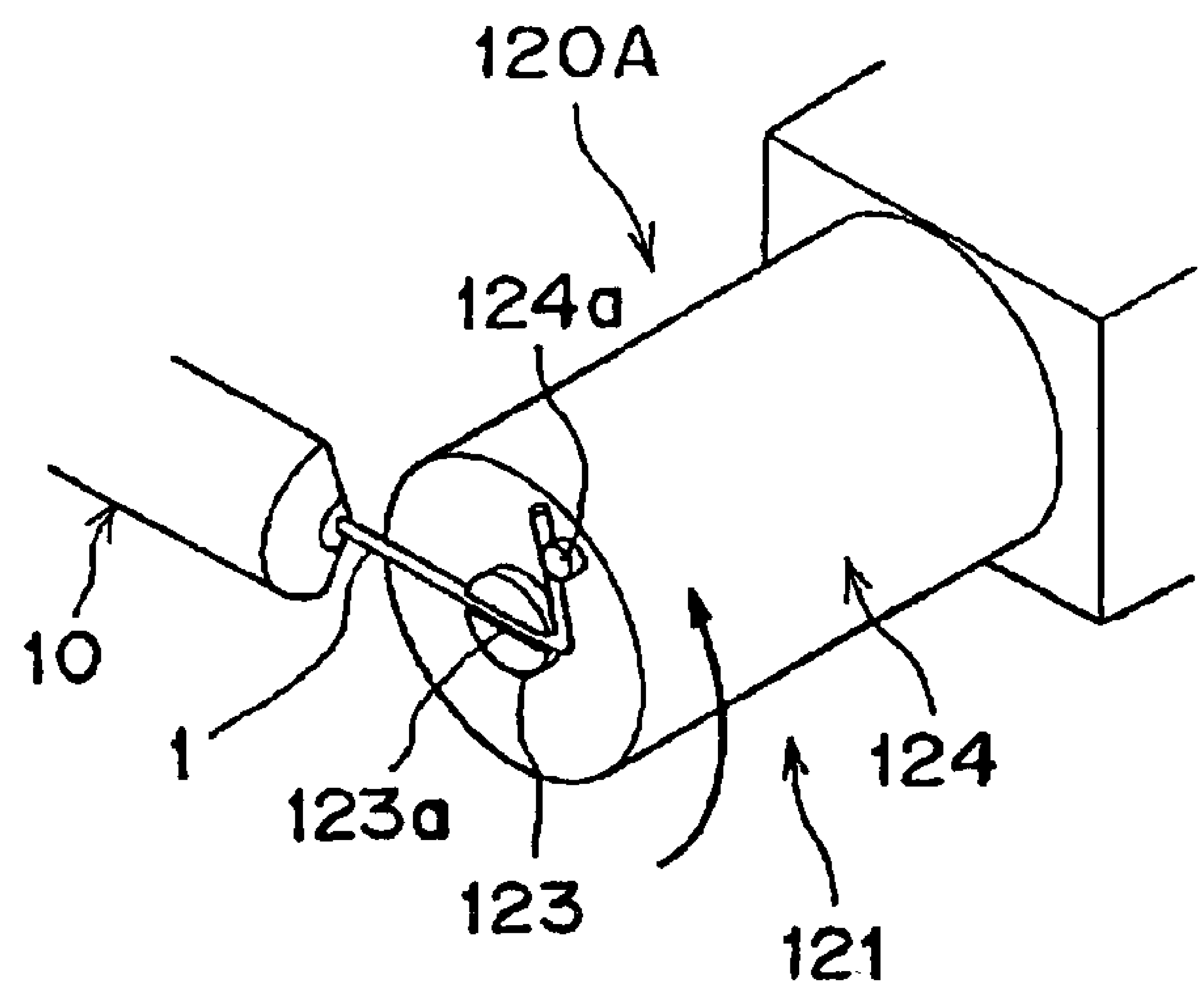


Figure 8

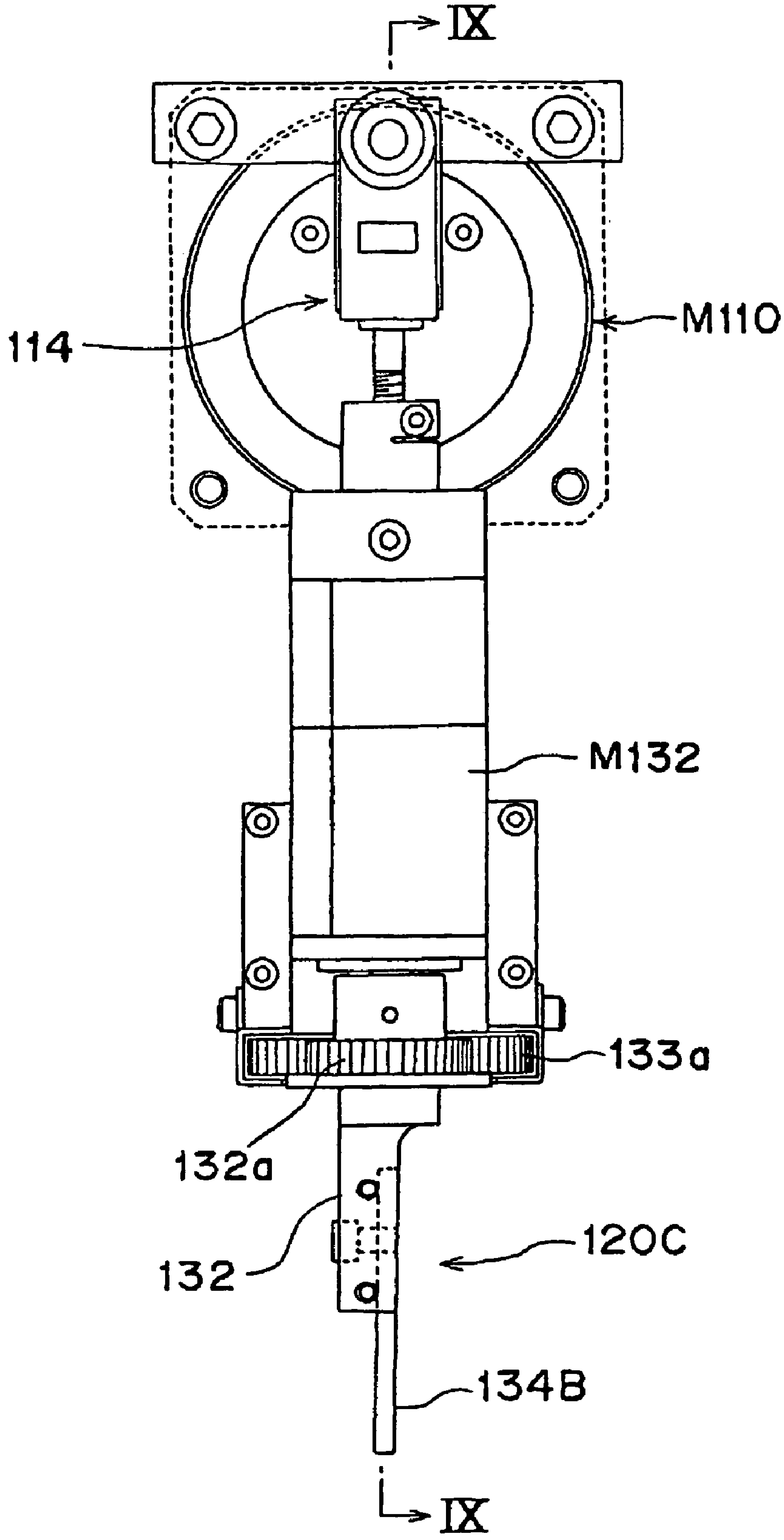
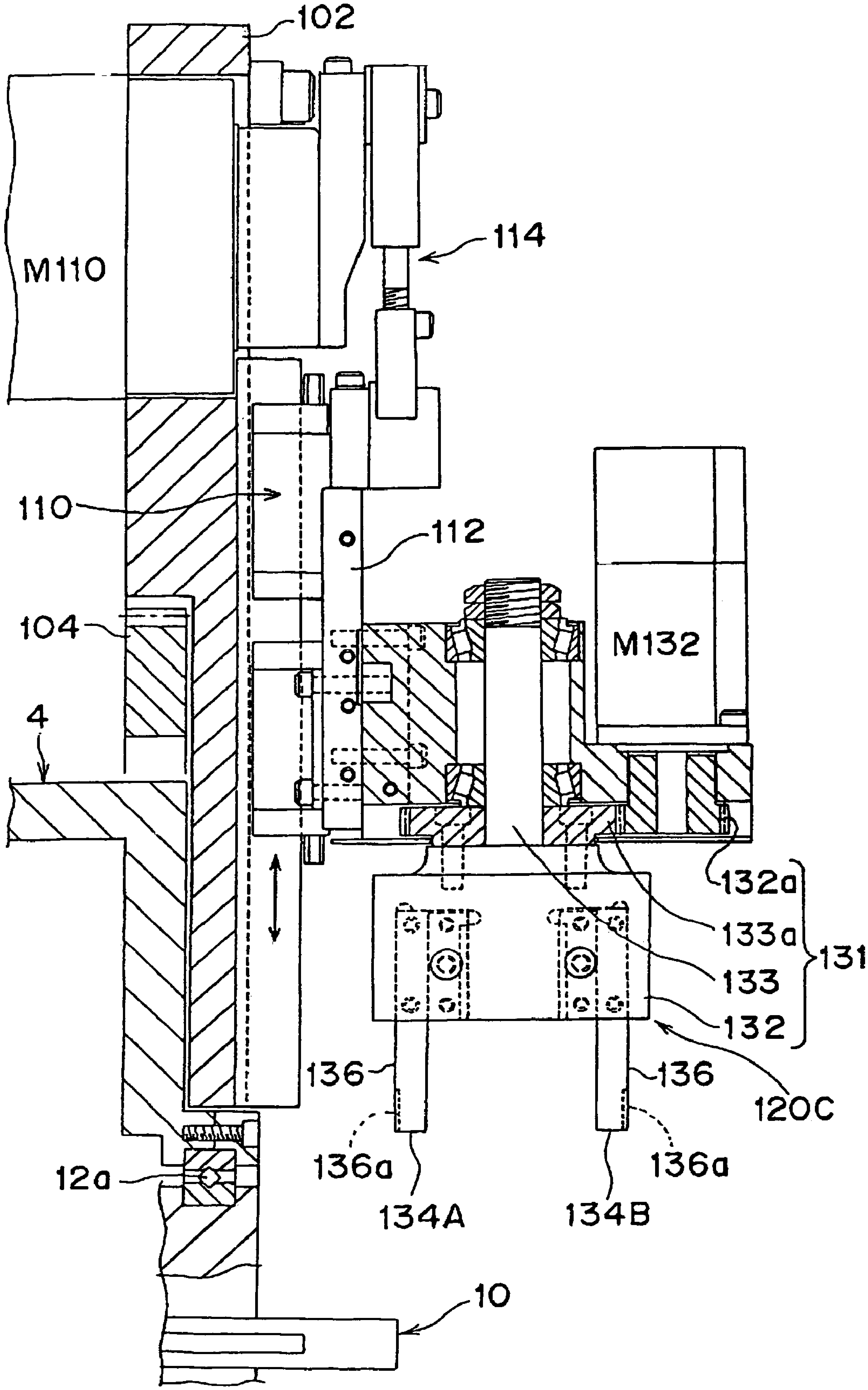


Figure 9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M110
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110
112
104
M132
4
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133a
131
133
132
136
136
120C
136a
136a
12a
134A
134B
10

Figure 10

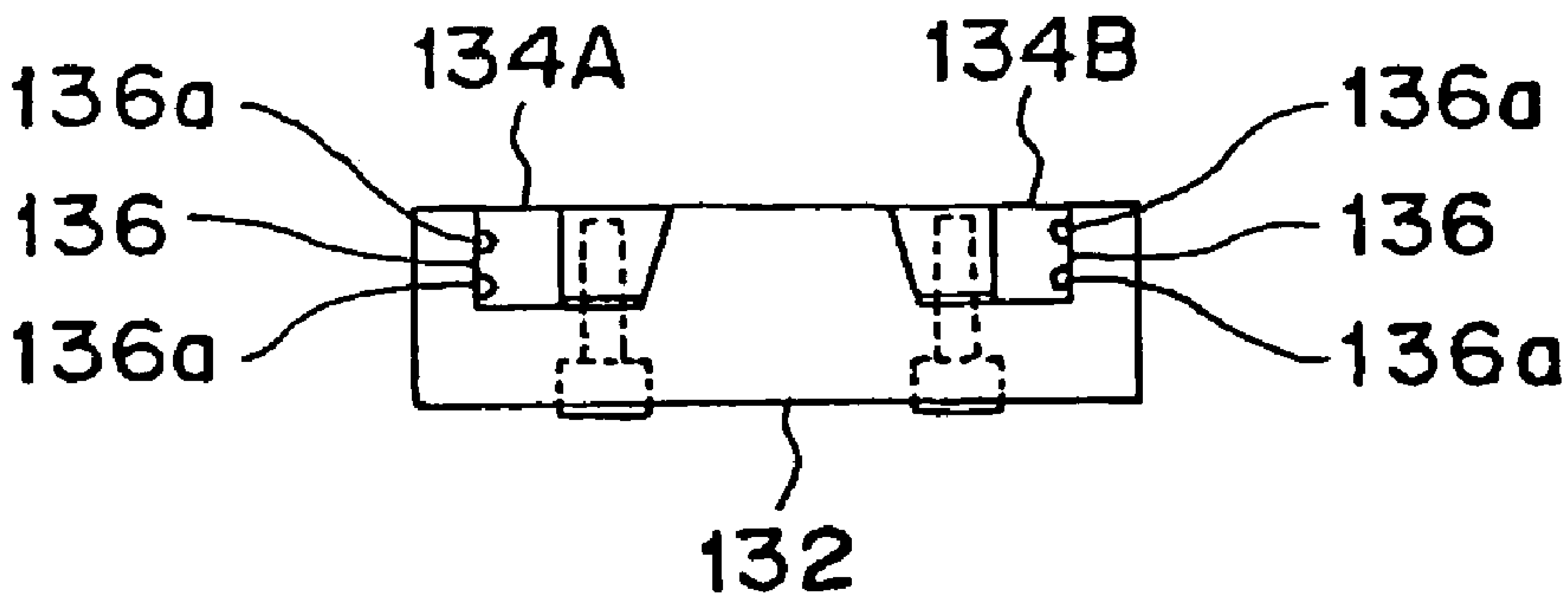


Figure 11

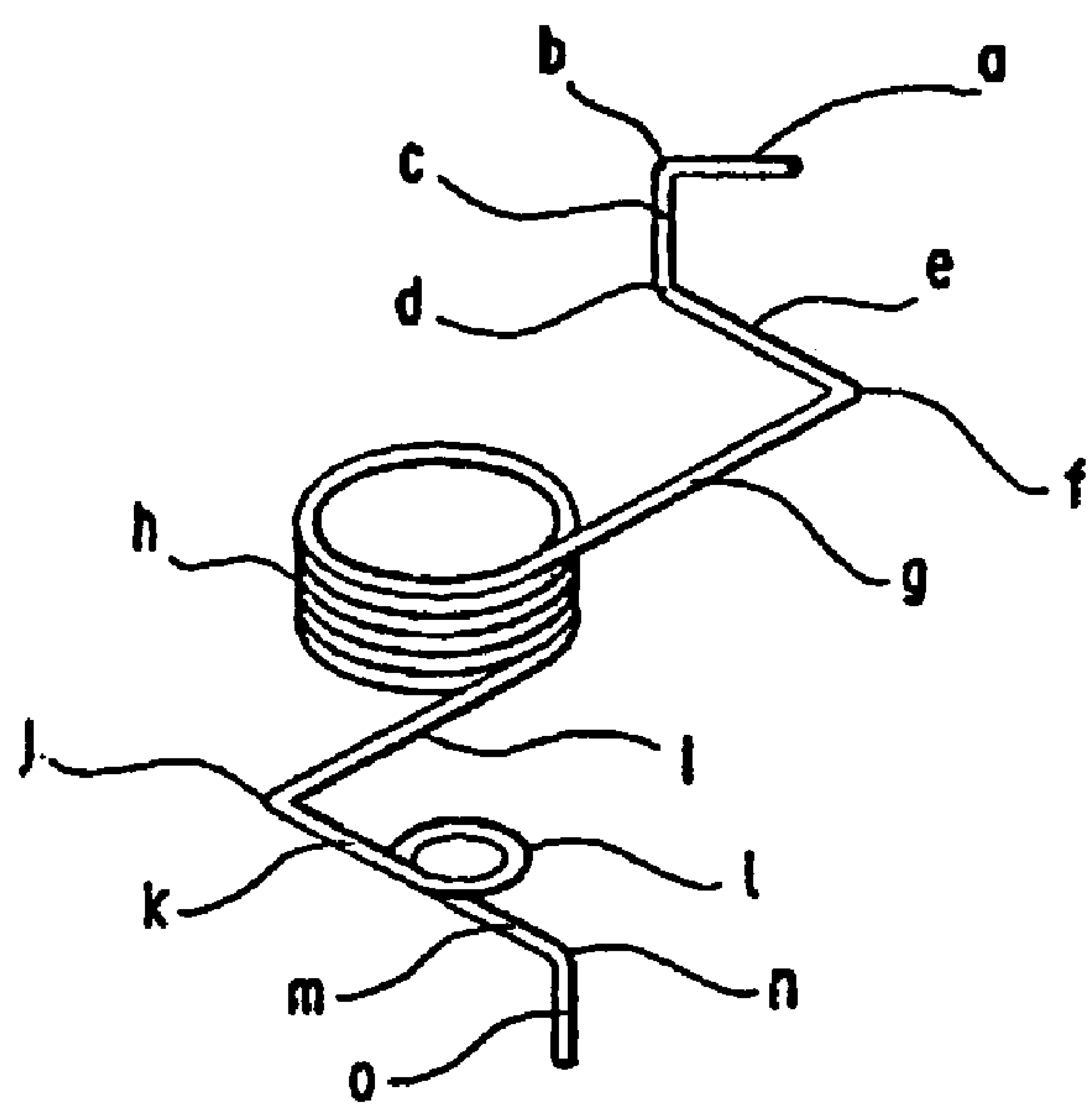
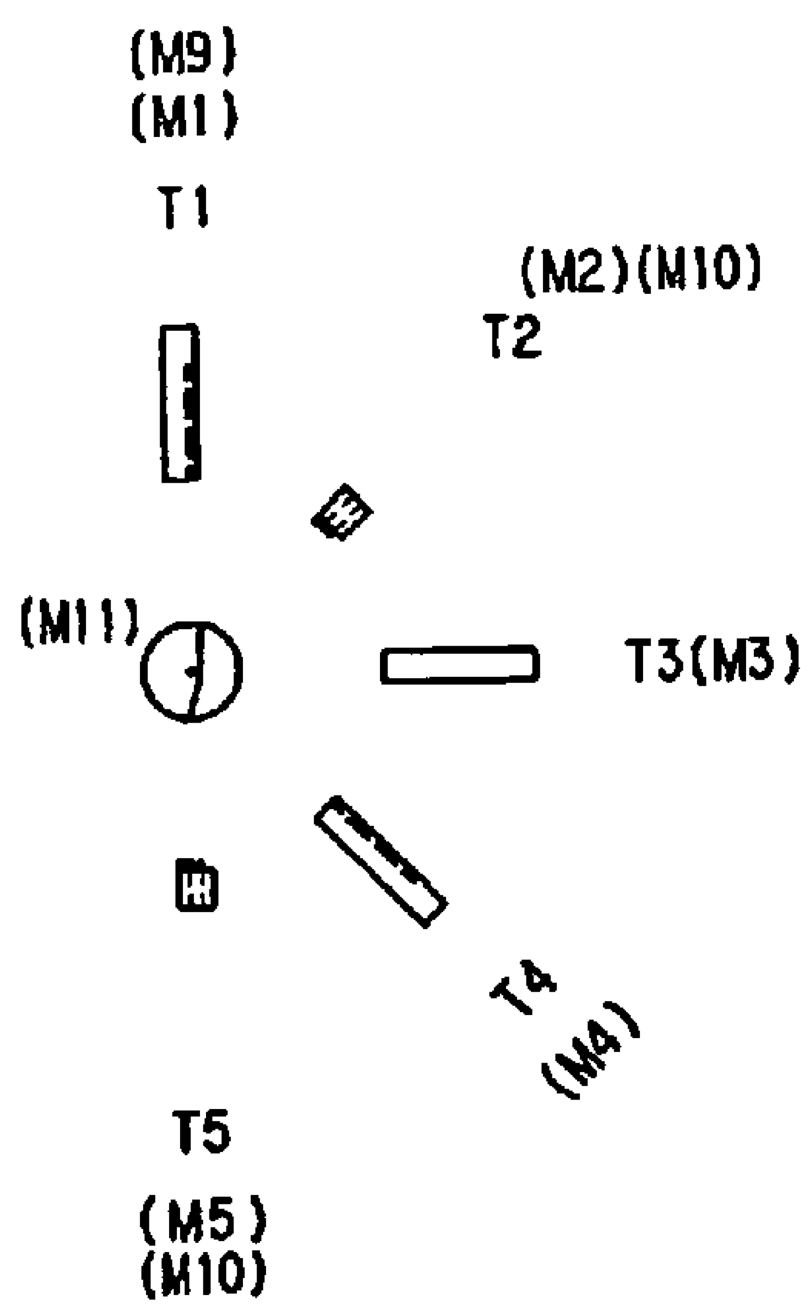
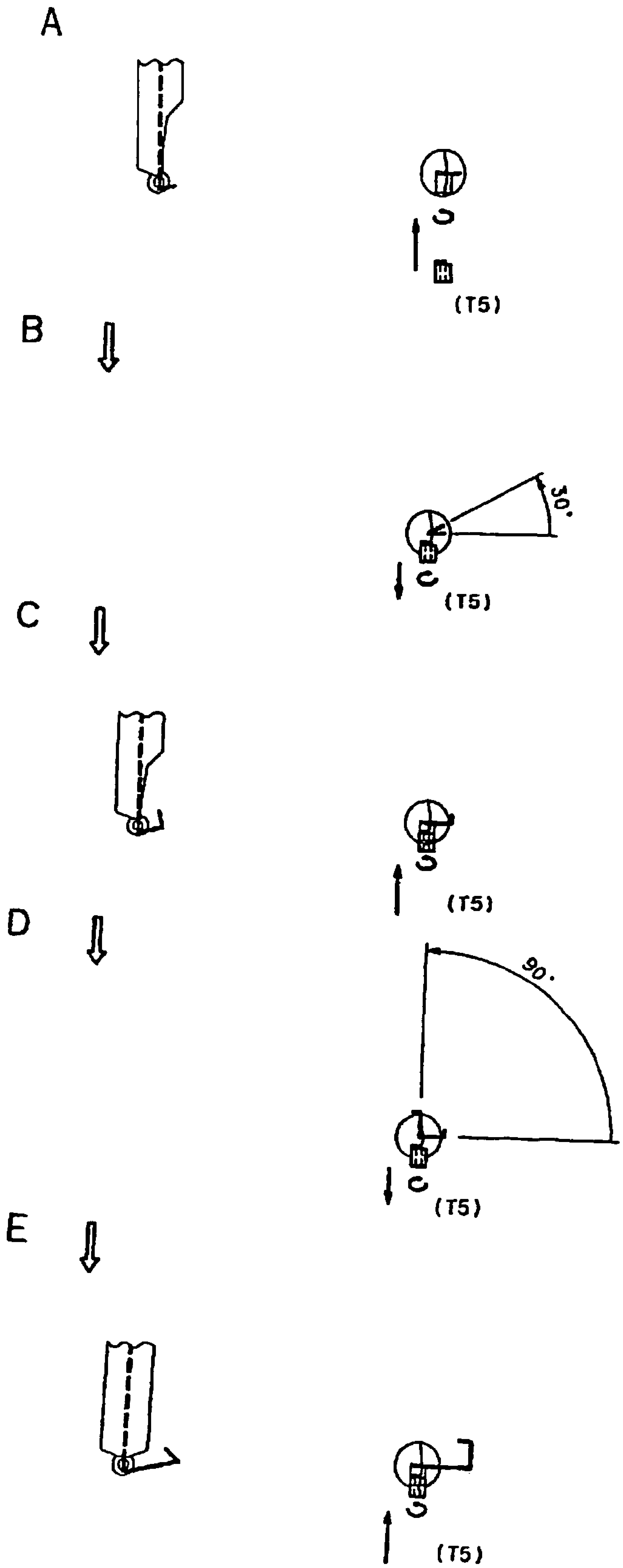


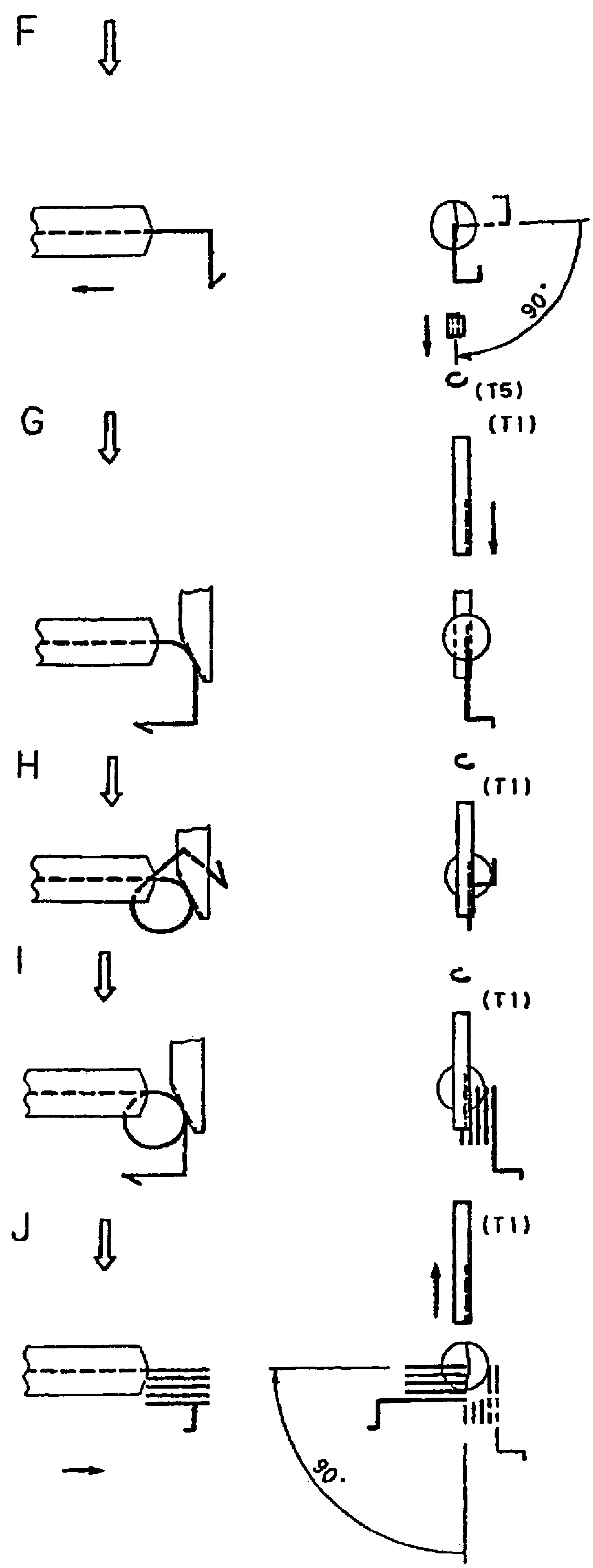
Figure 12



Figures 13



Figures 14



Figures 15

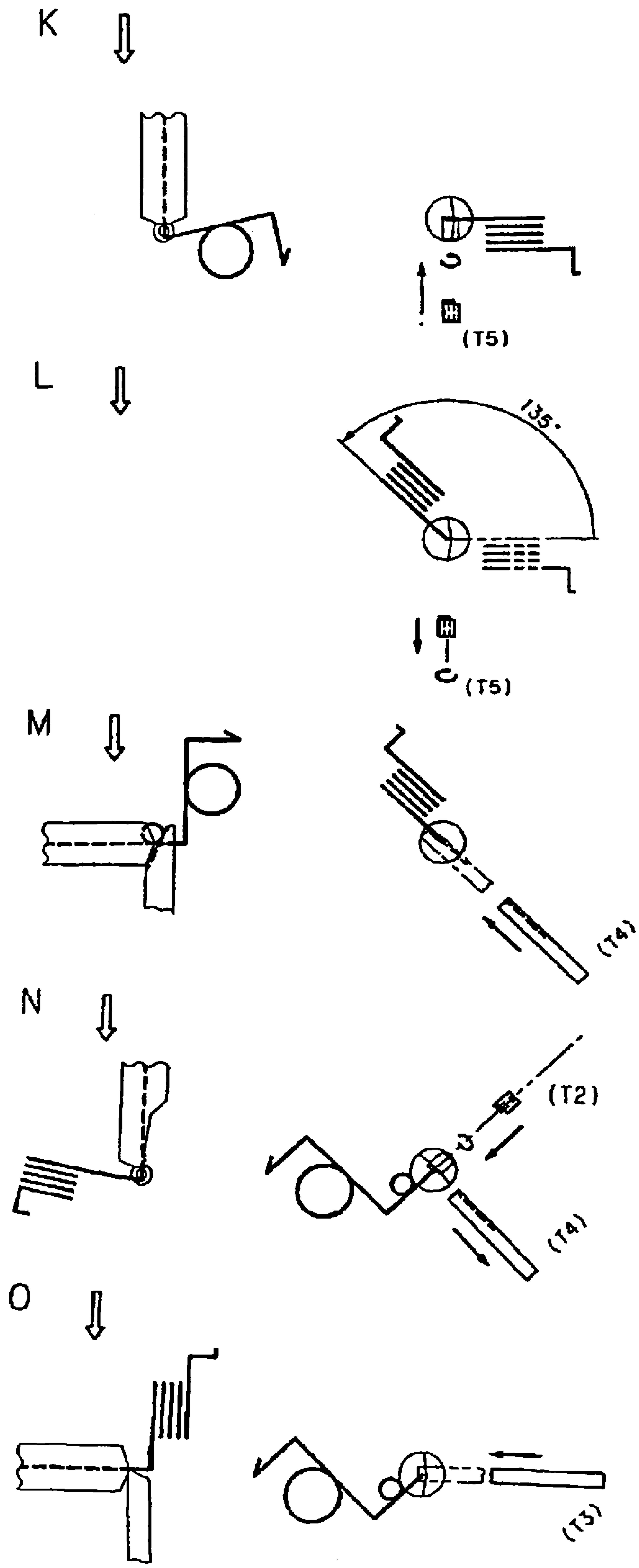
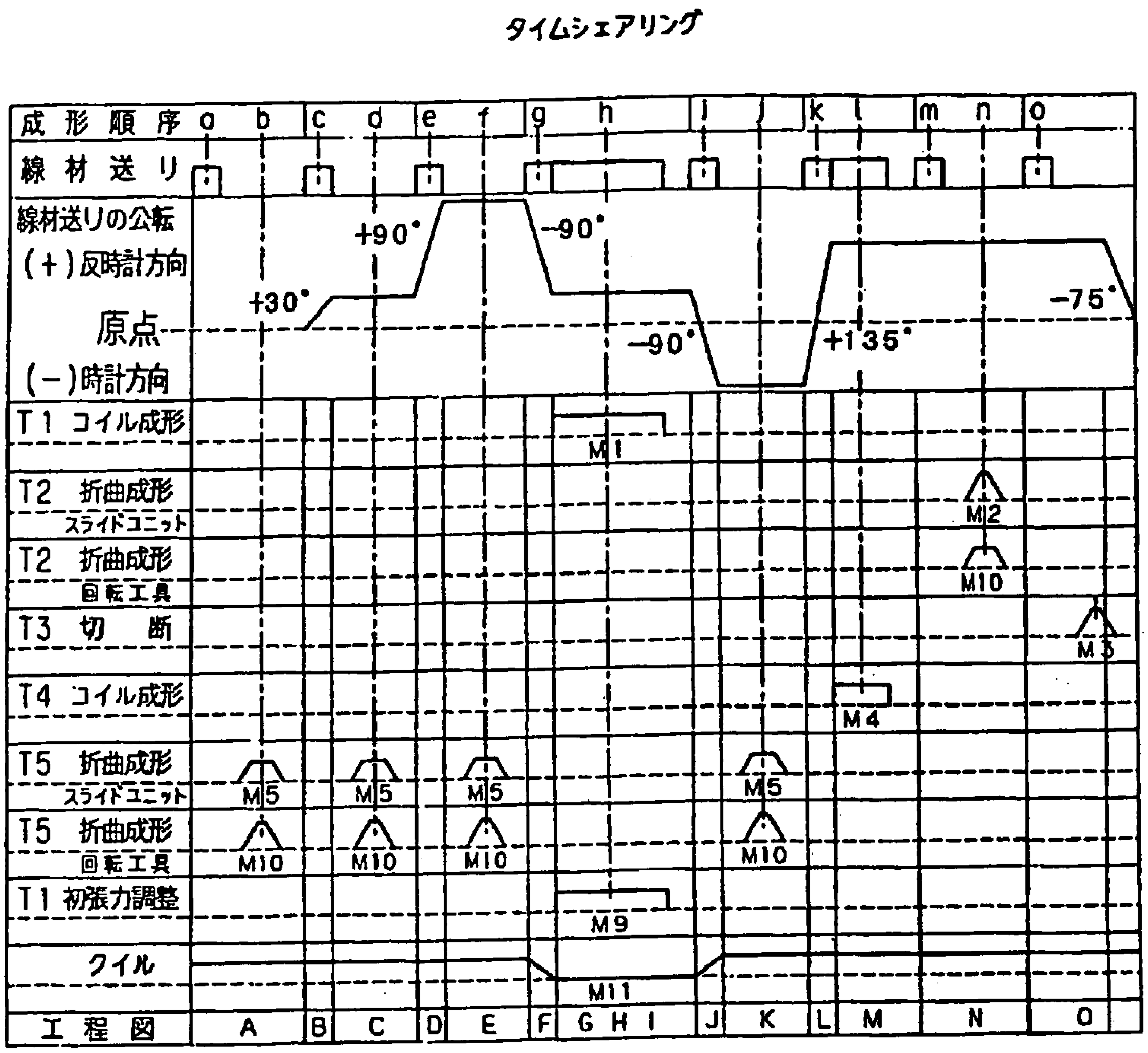


Figure 16


タイムシェアリング
成形順序
線材送り
線材送りの公転
(+)反時計方向
原点
(−)時計方向
T1 コイル成形
T2 折曲成形 スライドユニット
T2 折曲成形 回転工具
T3 切断
T4 コイル成形
T5 折曲成形 スライドユニット
T5 折曲成形 回転工具
T1 初張力調整
クイル
工程図
+30°
+90°
−90°
−90°
+135°
−75°
M1
M2
M10
M3
M4
M5
M9
M11
a b c d e f g h i j k l m n o
A B C D E F G H I J K L M N O

WIRE SPRING FORMING APPARATUS

FIELD OF THE INVENTION

The invention relates to an apparatus for forming a wire spring, the apparatus having a multiplicity of radially arranged spring forming tools that can be advanced to a spring forming stage, perpendicularly to the axis of a wire fed or guided by a quill mounted on the spring forming stage, until the tools abut the wire provided at the leading ends of the quill, thereby forming the wire spring.

BACKGROUND OF THE INVENTION

Japanese Patent Early Publication H10-29028 discloses an apparatus having means for feeding a wire including feeding rollers from a front quill to a spring forming stage, and multiple types of radially arranged spring forming tools, which can be advanced perpendicularly or substantially perpendicularly to the axis of the wire towards the spring forming stage until they abut the wire coming out of the quill. The spring forming tools are mounted on a swivel table and can be positioned at predetermined angular positions by turning the swivel table through predetermined angles. By advancing and retreating the spring forming tools in turn on the swivel table, the tools may abut the wire, bend it, curve it, or wind it to form a spring.

In this prior art wire spring forming apparatus, the radius of a coil of a spring can be varied by adjusting the distance from the quill (wire guide) to the tools that abut the wire in the process of forming the coil. A large distance is used to form a coil of a large diameter and conversely a small distance is used to form a coil of small diameter.

However, the above-mentioned prior art apparatus has a drawback in that in adjusting the radius of the coil it is necessary to adjust the positions of the spring forming tools with respect to the quill by manipulating screws provided on the spring forming tools (Literature 1, Paragraph 0022 and FIG. **8**), which is very tedious.

The prior art has another drawback in that the swivel table is provided with a set of 7 or 8 spring forming tools to attain high production efficiency. Hence, the entire swivel table, including its drive mechanism, has a considerably large moment of inertia. It is noted that the drive mechanism of each spring forming tool is set to have full advancing and receding strokes in order to prevent the mechanism from being damaged during its operation. Furthermore, each of the spring forming tools is programmed to be advanced only after the angular position of the swivel table is determined, and the swivel table is turned only after the relevant spring forming tool has finished its receding stroke. Because of the large amount of time involved in such processes and large moment of inertia of the spring forming tools, the production rate of the prior art spring forming apparatus is substantially lower than it might otherwise be. To overcome the difficulties associated with the simple advancing and retreating of spring forming tools as mentioned above, in which the wire is prevented from being scratched during the formation of a spring, it is also known to provide bending tools having a rotary body mounted on a mandrel and having projections on the periphery thereof. In order to mount this type of bending tool on the swivel table, two servomotors are provided to advance and retreat the tool and to rotate the bending tool. However, if more than one (2 say) such bending tools are mounted on the swivel table, an excessively large moment of inertia will result, so that in actuality only one bending tool can be mounted, which limits the production rate.

OBJECT OF THE INVENTION

It is, therefore, an object of the invention to overcome prior art problems mentioned above by providing a spring forming apparatus having a high production rate and being capable of easily adjusting the diameter of a coil spring to be formed.

SUMMARY OF THE INVENTION

The inventor has found that the aforementioned problems associated with prior art spring forming apparatuses can be solved as follows. First, rotation of the swivel table constituting a spring forming stage can be circumvented. This can be attained by allowing the feeding rollers holding the wire therebetween to revolve about the axis of the wire before a linear material, such as wire is fed therefrom to a spring forming stage ahead via a quill, thereby twisting and re-orienting the linear material. Thus, a multiplicity of bending tools need not be rotated and can be mounted on the table. This solution overcomes the second of the above-mentioned problems of low production rate. The first problem can be solved by providing a quill that can be moved in the axial direction of the linear material and electric motors adapted to numerically control the distance between the quill and the spring forming tools, thereby eliminating tedious manipulation of screws for adjusting the diameter of a coil to be formed. A trial spring forming apparatus based on these findings has been proven very efficient. Thus, the inventor has reached an inventive spring forming apparatus as disclose herein.

More specifically, the invention comprises a spring forming apparatus that includes:

means for forcibly feeding a linear material such as wire (referred to as wire feeding means) having at least a pair of feeding rollers for feeding the wire held therebetween to a spring forming stage located ahead via a quill; revolving means for revolving the feeding rollers about the axis of the wire to twist the wire fed out of the leading end of the quill, thereby changing the circumferential position, or angular position, of the wire relative to the spring forming stage; and

a multiplicity of spring forming tools arranged radially on the spring forming stage, each of the spring forming tools movable to and from the wire in a direction perpendicular or substantially perpendicular to the axis of the wire, the wire spring forming tools adapted to advance to abut on the wire fed out of the quill to the spring forming stage so as to bend, curve, or wind the wire, thereby forming a wire spring, wherein

the quill is movable in the axial direction of the wire by the action of quill moving means; and

motions of the wire feeding means, revolving means, and quill moving means are controllable.

As the pair of feeding rollers (of the wire feeding means) is revolved about the axis of the of wire, the wire held between the feeding rollers is twisted, thereby varying the angular position of the wire fed from the quill relative to the spring forming stage. Hence, by appropriately pre-setting the amount of revolution of the revolving means, the wire is twisted to an optimum angular position to abut on a predetermined one of the radially arranged spring forming tools. Thus, unlike in conventional apparatuses, the wire fed to the spring forming stage can be precisely bent, curved, and turned to form a coil spring without rotating the swivel table and generating a large moment of inertia.

It will be appreciated that by axially moving the quill by means of quill drive means, the distance between the quill and the spring forming tool, and hence the diameter of the coil formed, can be varied accordingly. As a result, the diameter of the coil can be freely changed by appropriately pre-setting the axial position of the quill driven by the quill drive means.

In accordance with another aspect of the invention, the wire spring forming apparatus may be characterized in that:

the quill moving means is a linear way slide table;

the quill is rotatable about the axis of the wire by means of quill rotating means; and

the quill rotating means, wire feeding means, and revolving means are axially fixed on the linear way slide table.

The quill alone can change its angular position while serving as a wire guide when rotated through a predetermined angle by means of the quill rotating means.

In accordance with still another aspect of the invention, the wire spring forming apparatus may also be characterized in that:

the spring forming tools are radially arranged, angularly spaced apart at regular angular intervals, on the front end of a main plate that constitutes the spring forming stage, each of the spring forming tools having a tool slide table driven in the radial direction thereof by a first servomotor via a crank mechanism to and away from the spring forming table;

the main plate has on the backside thereof a rotatably supported ring gear that surrounds the spring forming stage and driven by a second servomotor mounted on the main plate;

the tool slide table that constitutes a bending tool is provided with a rotational bending unit, and

a power transmission gear mechanism is provided between the rotational bending unit and the ring gear to transmit the torque of the ring gear to the rotational bending unit without interfering the advancing and receding motions of the tool slide table.

As an example, the rotational bending unit can be formed of (1) a fixed mandrel having a groove formed in the front end thereof facing the axis of the wire, and (2) a rotary body having a protrusion formed on the front end thereof for engagement with the wire (the protrusion referred to as wire engaging projection) and rotatably supported on the periphery of the fixed mandrel.

In the invention, the torque of a ring gear driven by a single second servomotor is transmitted to a multiplicity of rotational bending units arranged on the main plate via respective power transmission gear mechanism mounted between the main plate and the respective rotational bending units, thereby rotating the respective rotational bending units. The rotational motion of the bending tool does not interfere with the advancing and receding motions of the slide tables, so that the bending tools can be individually advanced, retreated, and rotated freely at any time.

It is noted that although all the rotational bending units mounted on the main plate, including those bending tools currently not in operation, are rotated, there are at most four bending tools and the load imposed on the second servomotor is not very large as compared with the load that would be imposed on individual servomotors provided for individual bending tools. Hence, smooth and speedy rotation of the ring gear can be attained by the second servomotor.

In order to reduce the bending stress on the main plate due to the weight of the second servomotor and to ensure stability of the main plate, the second servomotor is preferably mounted at a position below the main plate for which the center of gravity of the entire plate is sufficiently low.

In accordance with a further aspect of the invention, the wire spring forming apparatus may also be characterized in that:

the power transmission gear mechanism has a drive shaft installed on the main plate in parallel with the sliding direction of the tool slide table and a coaxial driven shaft installed on the rotational bending unit such that the drive shaft and driven shaft are mutually slidable in the coaxial direction but locked in the circumferential direction.

In the operably connected section of the drive shaft mounted on the main plate and the driven shaft coaxial with the drive shaft, the driven shaft can axially slide relative to the drive shaft, allowing the tool slide plate to smoothly advance and recede. On the other hand, the torque of the ring gear is transmitted to the rotational bending unit via the coaxial drive shaft and driven shaft, since they are locked in the circumferential direction.

In a case where the drive shaft mounted on the main plate is a circular cylinder housing therein the coaxial driven shaft of the rotational bending unit in keyed engagement with each other by means of a key and a spline groove respectively formed on the inside and outside of the drive shaft and the driven shaft, secure spine engagement of the shafts can be obtained that provides proper axial sliding displacement of one shaft to another while locking them in the circumferential direction. Such spline engagement is compact in size but may provide a long reach in the axial direction.

The wire spring forming apparatus may further be characterized in that holes for installing the respective transmission gear mechanisms are formed in the main plate at regular angular intervals.

Holes for mounting power transmission gear mechanisms are formed in the main plate at the positions (angularly spaced at regular intervals) where the respective spring forming tools are mounted, so that any bending tool may be arranged at these positions.

The wire spring forming apparatus may further be characterized in that

each of the tool slide tables constituting a coil forming tool is provided with a tool rotating unit having a pair of dextral and sinistral coil forming work heads mounted on a rotatable tool holder having a rotary shaft oriented in the direction parallel to the advancing/receding direction of the tool slide table, the coil forming work heads opposing each other across the rotary shaft; and

a third servomotor is provided for rotating the tool holder.

The initial tension of wire forming a coil can be adjusted by shifting the wire engaging groove of the coil forming work heads by a predetermined distance relative to the wire. This can be done by rotating the third servomotor only slightly while forming the coil. In this coil forming tool, dextral and sinistral coil forming work heads to be engaged with the wire on the spring forming stage can be switched by actuating the third servomotor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front view of the entire spring forming apparatus according to a first embodiment of the invention.

FIG. **2** is a left side view, partially shown in cross section, of the apparatus shown in FIG. **1**.

FIG. **3** is a horizontal sectional view of a portion of the apparatus including a rotational frame.

FIG. **4** is an enlarged sectional view near a quill of the apparatus.

FIG. **5** is a front view of a bending tool of the apparatus.

FIG. **6** is a longitudinal sectional view of the bending tool taken along line VI—VI of FIG. **5**.

FIG. **7** is a perspective view of a main section of the bending tool.

FIG. **8** is a plan view of a coil forming tool.

FIG. **9** is a longitudinal sectional view of the coil forming tool taken along line IX—IX of FIG. **8**.

FIG. **10** shows an arrangement of a dextral and a sinistral coil forming work heads formed on a tool holder;

FIG. **11** shows an example of spring formed by the spring forming apparatus.

FIG. **12** shows an arrangement of different types of spring forming tools located on the respective spring forming stages.

FIGS. **13**–**15** together show steps of forming a wire spring shown in FIG. **11**.

FIG. **16** shows a time-sharing scheme in the spring forming steps for the spring shown in FIG. **11**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The invention will now be described in detail by way of examples with reference to the accompanying drawings.

FIGS. **1**–**16** show a spring forming apparatus in accordance with a first embodiment of the invention. More particularly, FIG. **1** shows a front view of the apparatus; FIG. **2** shows a left elevation, partly in cross section; FIG. **3** shows a horizontal cross section of a portion of the apparatus including a rotational frame; FIG. **4** shows an enlarged cross section of the apparatus near the quill; FIG. **5** shows a front view of a bending tool of the spring forming apparatus; FIG. **6** shows a longitudinal cross section of the bending tool taken along line VI—VI of FIG. **5**; FIG. **7** shows a perspective view of the main section of the bending tool; FIG. **8** shows a plan view of a coil forming tool; FIG. **9** shows a longitudinal cross sectional of the coil forming tool taken along line IX—IX of FIG. **8**; FIG. **10** shows an arrangement of a dextral and a sinistral coil forming work heads formed on a tool holder; FIG. **11** shows a perspective view of a spring formed by the spring forming apparatus; FIG. **12** shows an arrangement of different spring forming tools on a spring forming stage; FIGS. **13**, **14**, and **15** together show a process of forming a spring shown in FIG. **11**; FIG. **16** shows a time sharing scheme in the process of forming the spring shown in FIG. **11**.

While the embodiment of the invention is described with respect to a feeding means and feeding guide for wire, it should be noted that the invention encompasses a spring forming apparatus capable of forming a spring from any suitable linear material regardless of the specific cross sectional shape of the linear material.

As shown in these figures, the spring forming apparatus comprises:

a feeding means **20** having a pair of feeding rollers **22** for feeding a linear material such as a wire **1** held between them via a quill **10** serving as a wire feeding guide to a forward spring forming stage **100** (FIGS. **1**, **2**, and **6**); a revolving means **30** for revolving the wire feeding means **20** about the axis X**1** of the wire **1** to twist the wire **1**, thereby varying the angular position, relative to the spring forming stage **100**, of the wire **1** fed from the leading end of the quill **10**;

a quill rotating means **40** for rotating the quill **10** about the axis X**1** of the wire **1**;

a multiplicity (**5** in the example shown herein) of spring forming tools **120** (**120**A–**120**E) radially arranged on the spring forming stage **100** and capable of advancing and receding at right angles or substantially right angles to the axis X**1** of the wire **1**, wherein

the spring forming tools **120** are advanced to abut on the wire **1** so as to bend, curve, or turn the wire **1**, thereby forming a wire spring.

A rectangular platform **2** shown in FIGS. **1** and **2** supports from below the revolving means **30**, the quill rotating means **40**, and the spring forming stage **100** and houses therein a multi-shaft numerical control unit for numerically controlling the servomotors driving the wire feeding means **20**, revolving means **30**, and quill rotating means **40** as well as other drive means of the wire spring forming apparatus in coordination.

Mounted on the platform **2** is a fixed frame **3**, which is integral with a vertically mounted main plate **102** that constitutes the spring forming stage **100**, such that the axis X**1** of the wire **1** is aligned with the center of the main plate main plate **102**.

Provided on the fixed frame **3** is a linear way slide (quill moving means) **50** (FIG. **2**) for advancing and retreating the quill along the axis X**1** of the wire **1**. That is, assembled on the fixed frame **3** is a slide table **52** which is slidable along the axis X**1** of the wire **1**. The wire feeding means **20**, the revolving means **30**, and the quill rotating means **40** are integrally mounted on the slide table **52** via a slide frame **4**. The slide table **52** can be advanced and retreated along the axis X**1** of the wire **1** by means of a ball screw **54** which is driven by a servomotor M**50** mounted on the fixed frame **3**. In forming a wire spring by advancing predetermined spring forming tools **120** towards the spring forming stage **100** and engaging with the wire **1** fed from the quill **10** to bent, curve, or turn the wire **1**, the diameter of the coil spring may be freely regulated by adjusting the shifted position of the slide table **52** (or quill **10**) through numerical control of the servomotor M**50**, since the diameter of the coil spring is proportional to the distanced between the spring forming tool **120** and the quill **10**.

As shown in FIGS. **2**–**4**, the wire feeding means **20** has a pair of feeding rollers **22**; a servomotor M**22** for driving the feeding rollers (referred to as feeding roller driving servomotor); a gear mechanism having gears "a–f" for transmitting the driving power of the servomotor M**22** to the feeding rollers **22**; an ordinary wire correction mechanism **28**, mounted in the downstream of the feeding rollers **22**, for correcting bending of the wire **1**; and a guide ring mechanism **29** having a few guiding rollers **29***a* for holding the wire **1** oriented in a predetermined direction and feeding the wire **1** to the wire correction mechanism **28**.

The slide frame **4** rotatably supports the disk section **21***a* of a rotary frame **21** via cross roller bearings **31**. A rectangular gear housing section **21***b* (FIG. **3**) is provided, offset from a hole **24** formed at the center of the disk section **21***a* for passing therethrough the wire, whereby the feeding rollers **22** are mounted on one side of the gear housing section **21***b* such that their wire feeding path is aligned with the hole **24**. The driving force of the servomotor M**22** fixed on the disk section **21***a* is transmitted to the feeding rollers **22** via the gear mechanism (gear train) composed of the multiple gears a–f as shown in FIG. **3**. Specifically, the driving power of the servomotor M**22** is transmitted to the feeding rollers **22** by the gear "a" mounted on the output shaft of the servomotor M**22**, bipartite gears b**1** and b**2** supported by the disk section **21***a*, gears "c" and "d**1**" on a shaft **23** supported by the disk section **21***a*, and the gears "d**2**", "e", and "f" housed in the gear housing section **21***b*.

Fixed on the external side wall of the disk section **21***a* of the rotary frame **21** is a wire guide **25** (FIG. **4**) for guiding the wire to the entrance of the feeding rollers **22**. An intermediate quill **26** is fixed at the front end of the rotary frame **21**. The quill **10** supported around an intermediate quill **26** by the slide frame **4** via bearings **12***a* and **12***b* is rotatable relative to the intermediate quill **26**. After correction by the guide ring mechanism **29** and the wire correction mechanism **28**, the wire **1** is passed through a through-hole **24** of the rotational frame **21**, led to the paired feeding rollers **22** via the wire guide **25**, passed through the intermediate quill **26**, then guided by the quill **10** and fed to the forward wire spring forming stage **100**.

The revolving means **30** is formed of the wire feeding means **20** assembled on the slide frame **4** and rotatable as a whole about the axis X**1** of the wire **1**. That is, the rotary frame **21** constituting the revolving means **30**, wire correction mechanism **28**, and guide ring mechanism **29** are integrated as a revolving unit U**1** (FIGS. **2** and **3**), and the rotary frame **21** (disk section **21***a*) located at the front end of the revolving unit U**1** is rotatably supported by the slide frame **4** via the cross roller bearings **31**. The tailing frame **29***b* of the guide ring mechanism **29** located at the tailing end of the revolving unit U**1** is rotatably mounted, via bearings **32**, on an L-shaped frame **4***a* that extends rearwardly from the slide table **52**.

Mounted on the output shaft of a servomotor M**30** installed on the slide table **52** is a pinion gear **34** engaging with a ring gear **33** fixed on the disk section **21***a* of the rotary frame **21**, as shown in FIG. **2**. Hence, when driven by the servomotor M**30**, the entire revolving unit U**1** (wire feeding means **20**) revolves around the axis X**1**. In this context, the servomotor M**30** will be also referred to as revolution servomotor. Thus, a revolution of the wire feeding means **20** around the axis X**1** of the wire **1** causes the wire **1** to be twisted, thereby changing the angular position of the wire **1** fed by the quill **10** relative to the spring forming stage **100**. Thus, by numerically controlling the angle of revolution of the servomotor M**30**, the wire **1** on the spring forming stage **100** is twisted to the optimum angular position where it can be engaged with a predetermined one of the radially arranged spring forming tools **120**. It will be understood that unlike a conventional spring forming apparatus in which the swivel table is rotated to position the spring forming stage relative to the wire, the spring forming tools **120** of the invention are only advanced to abut on and retreat from the wire fed to the spring forming stage.

As shown in FIGS. **2** and **4**, the quill rotating means **40** includes: the quill **10** rotatably supported by the slide frame **4** via bearings **12***a* and **12***b*, a gear **44** provided on, and integrated with, the periphery of the quill **10**, an intermediate gear **46** supported by the slide frame **4** to abut on the gear **44**, and a pinion gear **48** mounted on the output shaft of a servomotor M**40** to engage with the intermediate gear **46**. It is noted that the quill **10** can be rotated alone, independently of the revolution of the entire wire feeding means **20** caused by the servomotor M**30**, to adjust its angular position relative to a predetermined spring forming tool **120** by actuating a servomotor M**40**.

As shown in FIGS. **1**–**2**, a multiplicity (**8** in the example shown herein) of linear slides **110** are provided in a radial arrangement about the center of (the spring forming stage **100** on) the main plate **102** and at right angles to the axis X**1** of the wire **1** aligned with the center of the main plate **102**. Each of the linear slides **110** is provided with a first servomotor M**110** for advancing and retreating a tool slide table **112** mounting thereon one of various types of spring forming tools **120**A–**120**E to and from the spring forming stage **100** located at the leading end of the quill **10**. Provided between the output shaft of the servomotor M**110** and the tool slide table **112** mounted on the main plate **102** is a crank mechanism **114** for converting the rotational motion of the servomotor M**110** into a linear motion, as shown in FIGS. **2**, **6**, and **9**, thereby controlling the advancing and receding motions of the tool slide table **112**.

In the example shown herein, spring forming tools **120** include bending tools **120**A and **120**B used to bend the wire, coil forming tools **120**C and **120**D for coiling the wire, and a cutting tool **120**E for cutting the wire. The cutting tool **120**E is a known tool, so that only the bending tools **120**A and **120**B and the coil forming tools **120**C and **120**D will be described in detail below.

Rotatably mounted on the backside of the main plate **102** is a ring gear **104**, surrounding the spring forming stage **100**, as shown in FIGS. **1**, **2**, **5**, and **6**. The ring gear **104** is supported by bearings **104***a*, as shown in FIG. **6**. The ring gear **104** abuts on a gear **105** mounted on the output shaft of a second servomotor M**121**. The ring gear **104** is rotated by the second servomotor M**121** to rotate rotary bodies **124** of the rotational bending units **121** of the respective bending tools (**120**A and **120**B).

Referring to FIGS. **5**–**7**, there is shown in detail the bending tool **120**A. The rotational bending unit **121** mounted on the tool slide table **112** of the bending tool **120**A includes a fixed mandrel **123** having a front end facing the axis X**1** of the wire **1** and provided with a wire receiving groove **123***a* and a projection **124***a*, adapted to abut on the wire **1**, also facing the axis X**1** of the wire **1**. (In what follows, the projection will be referred to as wire-abutting projection.) The rotational bending unit **121** also includes a rotary body **124** rotatably supported on the periphery of the mandrel **123**. A housing **122** is provided on the tool slide table **112** to house the rotational bending unit **121**. A driven shaft **125** is rotatably supported in parallel to the fixed central mandrel **123** in the housing **122**, as shown in FIG. **6**. A gear **125***a* mounted on the driven shaft **125** abuts on a gear **124***b* provided on the periphery of the rear end of the rotary body **124**.

The driven shaft **125** is integral with a coaxial spline shaft **126**. The spline shaft **126** abuts on a drive shaft in the form of a rotary cylinder **126***a* rotatably mounted on a frame **122***a* fixed on the main plate **102**. As a consequence, the spline shaft **126** and the rotary cylinder **126***a* are angularly locked with each other in the spline engagement section **129***a*, so that they can only slide on each other in the axial direction (as indicated by a double arrow in FIG. **6**) and can only rotate as a unit. A screw gear **126***b* threaded at 45 degrees and mounted on the rotary cylinder **126***a*, a screw gear **127***a* threaded at 45 degrees and mounted on the vertical rotary shaft **127** for engagement with the screw gear **126***b*, and a pinion **127***b* mounted on the shaft **127** for engagement with the ring gear **104** provided on the backside of the main plate **102** constitutes a power transmission gear mechanism **129**. The vertical rotary shaft **127** has a shank support fitted in fixing holes formed in the main plate **102** and adjacent the linear slides **110**. The vertical rotary shaft **127** passes through the main plate **102** and vertically extends out of the front end of the main plate **102** so that the rotation of the ring gear **104** is transmitted to the rotary cylinder **126***a* and the driven shaft **125** via the vertical rotary shaft **127** and the screw gears **127***a* and **127***b*, and further to the rotary body **124** via the gears **125***a* and **124***b*.

It is noted that the driving force of the motor M**110** is transmitted to the tool slide table **112** via the crank mechanism **114** to advance and retreat the tool slide table **112**. But since the rotational bending unit **121** and the driven shaft **125** mounted on the tool slide table **112** by means of the housing **122** can slide in the axial direction in the coupling section (or spline engagement section) **129***a* between the spline shaft **126** integrated with the driven shaft **125** and the rotary cylinder **126***a* supported on the main plate **102** via the frame **122***a*, the tool slide table **112** (and hence the bending tool **120**A) can smoothly slide (i.e. advance and retreat) when driven by the servomotor M**110**.

Thus, as the servomotor M**110** is actuated to advance the bending tool **120**A and the servomotor M**121** is actuated to rotate the rotary body **124** while keeping the wire **1** in engagement with the groove **123***a* of the mandrel **123** as shown in FIG. **7**, the portion of the wire **1** held by the wire engaging projection **124***a* is bent at the section which is in engagement with the groove **123***a* of the mandrel **123**. It is noted that the wire **1** can be bent either to the right or left depending on the direction of the rotation of the rotary body **124**.

Details of the bending tool **120**B will be omitted since it has the same structure as the bending tool **120**A.

Incidentally, when the ring gear **104** is rotated by the servomotor M**121**, the rotary body **124**, and hence the rotational bending units **121**, of the bending tools **120**A and **120**B are simultaneously rotated. However, in forming a spring, only one (rotary body **125** of the) rotational bending unit **121** of the bending tools **120**A or **120**B will be used at a time, and the other one will be idling. Therefore, the load of the servomotor M**121** is not very large as compared with the load of a tool in which only one (rotary body **124** of the) rotational bending unit **121** is driven. Hence, smooth and swift rotation of (the rotary bodies **124** of) the rotational bending units **121** can be attained to bend the wire **1**.

It will be appreciated that the servomotor M**121** is disposed at a lower position of the main plate **102** to lower the center of gravity of the main plate **102**. This helps reduce the bending torque acting on the main plate **102** due to the weight of the servomotor M**121** and hence secure the stability of the main plate **102**.

Details of the coil forming tools **120**C and **120**D are shown in FIGS. **8**–**10**. Each of the coil forming tools **120**C and **120**D has a tool rotating unit **131** mounted on the tool slide table **112** and having a pair of sinistral and dextral coil forming work heads **134**A and **134**B, respectively, opposing each other across a rotary shaft **133** for forming a dextral and a sinistral coil, respectively, both heads mounted on a generally planular tool holder **132**. The tool holder **132** is a rotary body adapted to rotate about the rotary shaft **133** extending in the direction of the advancing/receding motion of the tool slide table **112**. The coil forming tool is also provided with a servomotor M**132** for rotating the tool rotating unit **131** (i.e. rotating the tool holder **132**). A gear **132***a* mounted on the output shaft of the servomotor M**132** abuts on a gear **133***a* mounted on the rotary shaft **133** to transmit the driving power of the servomotor M**132**.

In the coil forming tool **120**C, positions of the sinistral and dextral coil forming work heads **134**A and **134**B, respectively, can be reversed by simply operating the servomotor M**132**, so that the sinistral and dextral coil forming work heads **134**A and **134**B, respectively, can be easily switched on the spring forming stage **100** for engagement with the wire **1**.

As shown in FIG. **10**, the sinistral and dextral coil forming work heads **134**A and **134**B, respectively, are provided at the left and the right corners of the tool holder **132**, which is a generally planular parallelepiped block, such that the wire engaging faces **136** each having an engaging groove **136***a* are oriented in the opposite directions. Hence, a long coil spring can extend without interfering the tool holder **132** while it is formed.

In forming a coil by fitting the wire **1** in the groove **136***a*, the initial tension of the coil can be adjusted by slightly rotating the tool holder **132** to displace the groove **136***a* by a predetermined (minute) distance. This adjustment initial can be easily attained by numerically controlling the servomotor M**132**.

The coil forming tool **120**D has the same structure as the coil forming tool **120**C, that details of the former coil will be omitted.

As described earlier, holes **106** are formed in the main plate **102**, at predetermined positions (spaced apart at regular angular intervals) for installing the power transmission gear mechanisms **129** (or the vertical rotary shafts **127**) of the respective bending tools, so that the bending tools **120**A and **120**B can be set up at any one of these angular positions. Thus, a wire spring forming apparatus of the invention has a great design freedom regarding the arrangement of the spring forming tools, thereby making the design of a wire spring forming apparatus easier.

Next, a procedure of forming a wire spring using a wire spring forming apparatus of the invention will now be described with reference to FIGS. **11**–**16**.

FIG. **11** is a perspective view of an exemplary wire spring to be formed. The spring is formed of sections “a–o”, beginning with the section “a”. FIG. **12** shows an arrangement of the spring forming tools, in which symbols T**1**–T**5** refer to coil forming tools set up at the positions indicated by these symbols. More particularly, symbols T**1** and T**4** refer to coil forming tools **120**C and **120**D (having respective work heads) when they are set up at these positions; symbols T**2** and T**5** refer to bending tools **120**B and **120**A (equipped with respective work heads) when they are set up at these positions; and T**3** refers to a cutting tool **120**E (having a cutting work head) when it is set up at this position. In what follows, therefore, a coil forming tool referred to by Tj (j=1 to 5) will be referred to as coil forming tool Tj. In forming a sinistral coil, only the coil forming tool **120**C (that includes a sinistral coil forming work head **134**A) is used as the coil forming tool T**1**. In forming a dextral coil, only the coil forming tool **120**D (that includes a dextral coil forming work head **134**B) is used as the coil forming tool T**4**. The bending tool **120**B is used as a bending tool T**2** to form a sinistral spring, while the bending tool **120**A is used as a bending tool T**5** to form a dextral spring.

Servomotors M**110** are arranged at positions M**1**–M**5** (referred to as motors M**1**–M**5**) for advancing and retreating the respective tool slide tables **112** mounting thereon respective spring forming tools T**1**–T**5**, as shown in FIG. **12**. A servomotor M**132** is arranged at position M**9** (referred to as servomotor M**9**) to rotate the coil forming tool T**1**. Servomotors M**121** are arranged at positions M**10** (referred to as motors M**10**) to rotate the bending tools T**1** and T**5**. A servomotor M**50** is arranged at position M**11** (referred to as servomotor M**11**) to advance and retreat the slide table **52**. FIGS. **13**–**15** together show **15** steps A–O of a process of forming a wire spring. FIG. **16** shows a time sharing scheme applied to the process of forming the wire spring shown in FIG. **11**.

To begin with, the servomotor M**22** is actuated to drive the feeding rollers to feed a predetermined length of the wire **1** to form the section “a”. As the servomotor M**5** is actuated to advance the bending tool T**5**, the groove **123**_a_ of the mandrel **123** abuts on wire **1**. As the servomotor M**10** is actuated, the rotary body **124** is rotated to form a kink “b”. Then the bending tool T**5** is retreated away from the wire **1**.

Next, in step B, the wire **1** is rotated in the counterclockwise direction by the revolution servomotor M**30** through an angle of 30 degrees while the bending tool T**5** is held in the retreated position. During this rotation, a length of wire is further fed out of the quill by the servomotor M**22** driving the feeding rollers, thereby forming the section “c”.

Next, in step C, the servomotor M**5** is actuated to advance the bending tool T**5** forward until the groove **123**_a_ of the mandrel **123** abuts on the wire **1**. The servomotor M**10** is then actuated to rotate the rotary body **124** to form the bent section “d”, after which the bending tool T**5** is retreated away from the wire **1**.

Next, in step D, the wire **1** is rotated through 90 degrees (+90°) in the counterclockwise direction by the revolution servomotor M**30** while keeping the bending tool T**5** in the retreated position and feeding the wire **1** by a predetermined length for the section “e” by actuating the feeding roller driving servomotor M**22**.

Next, in step E, servomotor M**5** is actuated to advance the bending tool T**5** until the groove **123**_a_ of the mandrel **123** abuts on the wire **1**, and servomotor M**10** is actuated to rotate the rotary body **124** to form the section “f”. The bending tool T**5** is then retreated.

Next, in step F, the revolution servomotor M**30** is actuated to rotate the wire **1** through 90 degrees (−90°) in the clockwise direction while keeping the bending tool T**5** in the retreated position. Meanwhile, the motor M**11** (i.e. servomotor M**50** for sliding the slide table **52**) is actuated to retreat the quill **10** to a position to form a coil spring of a given diameter. At the same time, the wire **1** is fed out of the quill by a length necessary to form the section “g” by actuating the feeding roller driving servomotor M**22**.

Next, in step G, the servomotor M**1** (servomotor M**110** arranged at position M**1**) is actuated to advance the coil forming tool T**1** to a predetermined position. Then, in step H, the wire **1** is fed to form the coil section “h” by actuating the feeding rollers driving servomotor M**22** until the wire **1** is coiled for a required number of turns. It is noted that in forming the coil section “h” in steps G, H, and I, the initial tension of the coil to be formed may be adjusted by slightly shifting the work head (or wire engaging groove **136**_a_) relative to the wire **1** in the transverse direction of the groove **136**_a_. This can be done by actuating the servomotor M**9** (or actuating the servomotor M**132** to rotate the coil forming tool T**1**), and hence the tool rotating unit **131** (or tool holder **132**). When the coil section “h” is finished by the coil forming tool T**1**, the coil forming tool T**1** is retreated away from the wire **1**.

Next, in step J, the wire **1** is rotated in the clockwise direction through 90 degrees (−90°) by the revolution servomotor M**30** while keeping the T**1** in the retreated position. During this rotation, the quill **10** is advanced to its original position by actuating the servomotor M**11** (i.e. servomotor M**50** for sliding the slide table **52**). At the same time, the wire **1** is fed out of the quill for the length of the section “i” using the feeding rollers driven by the servomotor M**22**.

Next, in step K, the servomotor MS (servomotor M**110** for advancing and retreating the bending tool T**5**) is actuated to engage the groove **123**_a_ of the mandrel **123** of the bending tool T**5** with wire **1**, and then the servomotor M**10** (servomotor M**121** for rotating the bending tool T**5**) is actuated to rotate the rotary body **124**, thereby forming the kink “j”. The bending tool T**5** is then retreated away from the wire **1**.

Next, in step L, the wire **1** is rotated through 135 degrees (+135°) in the counter clockwise direction by the action of the revolution servomotor M**30** while keeping the T**5** in the retreated position. During this rotation, a length of the wire **1** is further fed out of the quill by the action of the servomotor M**22** driving the feeding rollers, thereby forming the section “k”.

In the next step M, the motor M**11** (i.e. servomotor M**50** for sliding the slide table **52**) is actuated to retreat the quill to adjust the axial position of the quill **10**. Then, the servomotor M**4** (i.e. the servomotor M**10**) is actuated to advance the coil forming tool T**4** until it abuts on the wire **1**. When the coil section “I” is finished by continuously feeding the wire **1** by the servomotor **22**, the feeding of the wire **1** is stopped and the coil forming tool T**4** is retreated away from the wire **1**.

In the next step N, the servomotor M**22** is actuated to feed the wire **1** for the section “m” while holding the coil forming tool T**4** in the retreated position. As the servomotor M**2** (i.e. servomotor M**110** for advancing and retreating the bending tool T**2**) is actuated to advance the mandrel **123** to engage the groove **123**_a_ with the wire **1** and servomotor M**10** (i.e. servomotor M**121** for rotating the bending tool T**2**) is actuated to rotate the rotary body **124**, forming the kink “n”, after which the bending tool T**2** is retreated away from the wire **1**.

In the next step O, the servomotor M**3** (servomotor M**22**) is driven to feed the wire **1** for the length of the section “**1**” and servomotor M**3** is actuated to advance the wire cutting tool T**3** to cut the wire **1**, allowing a formed spring shown in FIG. **11** to fall freely under the force of gravity. The wire cutting tool T**3** is then retreated away from the wire **1**.

Finally, the revolution servomotor M**30** is actuated to rotate the wire **1** in the clockwise direction through 30 degrees (−30°) to return the wire **1** to its original position (origin), thereby removing the twist of the wire **1**.

It should be understood that, although the coil forming tool T**1** is used as a dedicated sinistral tool for sinistral springs and the coil forming tool T**4** for dextral springs to avoid switching of the work heads, either one of the coil forming tools T**1** or T**2** could be used in the spring forming apparatus if the sinistral coil forming work head **134**A and dextral coil forming work head **134**B were made switchable.

In accordance with the invention, the diameter of the coil to be formed can be easily and arbitrarily altered by adjusting the axial position of the quill using a quill driving means. This is a great advantage of the invention over conventional ones in which the diameter is altered by manually operating adjusting screws.

Particularly, through the numerical control of the servomotors of the wire feeding means, revolving means, and quill moving means as described above, different types of springs having different diameters can be produced at a high production rate.

In accordance with the invention as defined in claim **2**, when the quill is utilized as a spring forming guide guiding the wire in the transverse direction and the quill is rotated to an optimum angular position (of a predetermined spring forming tool), the wire can be adequately bent.

Further, in accordance with the invention, each of rotary bodies of multiple bending tools can be rotated by a single servomotor mounted on the main flame that no other motor is needed except for the ones advancing and retreating the slide tables of the respective bending tools.

Also, bending tools can be smoothly advanced and retreated, which allows fast bending operations in the process of wire spring formation. Particularly, when the drive shaft of a bending tool mounted on the main plate has a form of circular cylinder housing therein a driven shaft of a rotational bending unit such that the two shafts are in spline engagement with each other and slidable in the axial direction but locked in the circumferential direction, the shafts allow not only accurate advance and retreat but also an accurate rotation of the bending tool. This enables production of high precision wire springs.

Bending tools may be arranged on the main plate at arbitrary angular positions around the spring forming stage, so that the wire spring forming apparatus has a large design freedom and is easy to design.

The initial tension of a coil to be formed can be easily adjusted by numerically controlling the a third servomotor.

Depending on which of a dextral coil and a sinistral coil is to be formed, a dextral and a sinistral coil forming work heads may be switched by actuating a third servomotor so that a formed coil will not interfere with the tool holder, regardless of the rection of winding of the coil. Consequently, it is possible to provide a coil having a long stem.

SYMBOLS

1 wire X**1** axis of wire
2 PLATFORM
3 FIXED FRAME
4 SLIDE UNIT
10 QUILL (WIRE GUIDE)
20 WIRE FEEDING MEANS
21 ROTATIONAL FRAME
21A DISK SECTION OF ROTATIONAL FRAME
22 FEEDING ROLLERS M**22** SERVOMOTOR FOR DRIVING FEEDING ROLLERS
30 REVOLVING MEANS
33 RING GEAR CONSTITUTING REVOLVING MEANS M**30** SERVOMOTOR FOR REVOLUTION
40 QUILL ROTATING MEANS M**40** SERVOMOTOR FOR ROTATING QUILL
50 LINEAR WAY SLIDE (QUILL MOVING MEANS)
52 LINEAR WAY SLIDE TABLE M**50** SERVOMOTOR FOR DRIVING LINEAR WAY SLIDE (FOR ADVANCING/RETREATING QUILL)
100 SPRING FORMING STAGE
102 MAIN PLATE
104 RING GEAR CONSTITUTING ROTATIONAL MECHANISM OF BENDING TOOLS
106 HOLES FOR INSTALLING POWER TRANSMISSION GEAR MECHANISM
110 LINEAR SLIDE M**110** SERVOMOTOR FOR ADVANCING/RETREATING SPRING FORMING TOOL (FIRST SERVOMOTOR)
112 TOOL SLIDE TABLE
114 CRANK MECHANISM FOR TRANSMITTING POWER OF FIRST SERVOMOTOR TO TOOL SLIDE TABLE
T(**120**) SPRING FORMING TOOLS
T**5**(**120**A) AND T**2**(**120**B) BENDING TOOLS
T**1**(**120**C) AND T**4**(**120**D) COIL FORMING TOOLS
T**3**(**120**E) CUTTING TOOL
M**121** SERVOMOTOR FOR ROTATING BENDING TOOL (SECOND SERVOMOTOR)
123 FIXED MANDREL CONSTITUTING ROTATIONAL BENDING UNIT
123*a* GROOVE FORMED IN THE FRONT END OF MANDREL TO ABUT ON WIRE
124 ROTARY BODY CONSTITUTING ROTATIONAL BENDING UNIT

124*a* PROJECTION FORMED ON THE FRONT END OF ROTARY BODY TO ABUT ON WIRE
125 DRIVEN SHAFT
126 SPLINE SHAFT OF ROTATIONAL BENDING UNIT SERVING AS DRIVEN SHAFT
127 VERTICAL ROTARY SHAFT
126*a* ROTARY CYLINDER SERVING AS DRIVE SHAFT
129 POWER TRANSMISSION GEAR MECHANISM FOR TRANSMITTING ROTIONAL POWER OF RING GEAR TO ROTARY BODY OF BENDING TOOL
129*a* SPLINE ENGAGEMENT SECTION OF POWER TRANSMISSION GEAR MECHANISM
132 ROTARY TOOL HOLDER FOR MOUNTING THEREON COIL FORMING WORK HEADS M**132** SERVOMOTOR FOR ROTATING COIL FORMING TOOL HOLDER (FOR SWITCHING SINISTRAL AND DEXTRAL COIL FORMING WORK HEADS AND ADJUSTING INITIAL TENSION OF WIRE) (THIRD SERVOMOTOR)
134A WORK HEAD FOR FORMING SINISTRAL COIL
134B WORK HEAD FOR FORMING DEXTRAL COIL

The invention claimed is:

1. A spring forming apparatus, comprising:

means for forcibly feeding a linear material having at least a pair of feeding rollers for feeding said material to a spring forming stage via a quill;

revolving means for revolving said feeding rollers about the axis of said linear material to twist the material fed out of the leading end of said quill, thereby changing the circumferential position, or angular position, of said material relative to said spring forming stage;

a multiplicity of spring forming tools arranged radially on said spring forming stage, each of which is movable to and from said linear material in a direction substantially perpendicular to the axis of the linear material, said spring forming tools adapted to be advanced to abut against said material fed to said spring forming stage so as to bend, curve, or turn said material, thereby forming a spring, and

a quill moving assembly for controllably moving and affixing said quill to a selected point in the axial direction of said linear material; wherein

motions of said feeding means, and revolving means, are controllable.

2. A spring forming apparatus, comprising:

means for forcibly feeding a linear material having at least a pair of feeding rollers for feeding said material to a spring forming stage via a quill;

revolving means for revolving said feeding rollers about the axis of said linear material to twist the material fed out of the leading end of said quill, thereby changing the circumferential position, or angular position, of said material relative to said spring forming stage;

a multiplicity of spring forming tools arranged radially on said spring forming stage, each of which is movable to and from said linear material in a direction substantially perpendicular to the axis of the linear material, said spring forming tools adapted to be advanced to abut against said material fed to said spring forming stage so as to bend, curve, or turn said material, thereby forming a spring, and

a quill moving assembly for moving said quill in the axial direction of said linear material; wherein

wherein motions of said feeding means, revolving means, and quill moving assembly are controllable; said quill moving assembly includes a linear way slide table; said quill is rotatable about the axis of said linear material by a quill rotating means; and said quill rotating means, feeding means, and revolving means are axially fixed on said linear way slide table.

3. A spring forming apparatus, comprising:

means for forcibly feeding a linear material having at least a pair of feeding rollers for feeding said material to a spring forming state via a quill;

revolving means for revolving said feeding rollers about the axis of said linear material to twist the material fed out of the leading end of said quill, thereby changing the circumferential position, or angular position, of said material relative to said spring forming stage;

a multiplicity of spring forming tools arranged radially on said spring forming stage, each of which is movable to and from said linear material in a direction substantially perpendicular to the axis of the linear material, said spring forming tools adapted to be advanced to abut against said material fed to said spring forming stage so as to bend, curve, or turn said material, thereby forming a spring, and

a quill moving means for moving said quill in the axial direction of said linear material;

wherein motions of said feeding means, revolving means, and quill moving means are controllable, and

said spring forming tools are radially arranged, and angularly spaced apart at regular angular intervals, on the front end of a main plate that constitutes said spring forming stage, each of said spring forming tools mounted on a tool slide table and driven in the radial direction thereof by a first servomotor via a crank mechanism to an away from said spring forming table;

said main plate having on the backside thereof a rotatably supported ring gear that surrounds said spring forming stage and is driven by a second servomotor mounted on said main plate;

each of the tool slide tables constituting a bending tool provided with a rotational bending unit, and

a power transmission gear mechanism is provided between said rotational bending unit and said ring gear to transmit the torque of said ring gear to said rotational bending unit without interfering with advancing and receding motions of said tool slide table.

4. The spring forming apparatus according to claim **3**, wherein

said power transmission gear mechanism has a drive shaft installed on said main plate in parallel with the sliding direction of said tool slide table and a coaxial driven shaft installed on said rotational bending unit such that said drive shaft and drive shaft are mutually slidable in the coaxial direction but locked in the circumferential direction.

5. The spring forming apparatus according to claim **3**, wherein holes for installing said transmission gear mechanisms are formed in the main plate at regular angular intervals.

6. The spring forming apparatus according to claim **3**, wherein

each of the tool slide tables constituting a coil forming tool is provided with a tool rotating unit having a pair of dextral and sinistral coil forming tools mounted on a rotatable tool holder having a rotary shaft oriented in the direction parallel to the advancing/receding direction of said tool slide table, said coil forming tools opposing each other across said rotary shaft; and further comprising:

a third servometer for rotating said tool holder.

7. The spring forming apparatus according to claim **1**, wherein said quill moving assembly includes a linear way slide table.

8. The spring forming apparatus according to claim **7**, wherein said quill moving assembly includes a ball screw convicted to said linear way slide table.

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